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ABSTRACT

Statistics on the allotment of funds and descriptions of activities carried out under the auspices of the National Science Foundation (NSF) in 1972 are reported. Details are provided for activities in the categories of (1) research project support, (2) national and international programs, (3) research applications, (4) science education research and programs, and (5) institutional programs. Among the appendices are a listing of staff, advisory committee, and panel members; details of organization changes and appointments, a financial report for 1972, a description of patents resulting from NSF-supported activities, and a publications list. (DT)

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National Science Foundation Annual Report 1972

NSF 73-1

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National Science Foundation

Twenty-Second Annual Report for Fiscal Year 1972

Letter of Transmittal

Washington, D.C.

Dear Mr. President:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1972 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

H. Guyford Stever
Director, National Science Foundation.

The Honorable
The President of the United States.

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1973

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Director's Statement

About 100 years ago, Henry Le Chatelier studied the thermodynamic behavior of disturbed systems. He noted that a stable system which has one of its conditions changed will adjust other conditions in the system so as to accommodate the change. Social systems tend to behave similarly. The National Science Foundation, as any other social system, also adapts in the face of change to reach a preferred state of equilibrium. In a way, the Foundation's record of the past year may be thought of as a search for new and better balances. Balance may be static, but the search for it is dynamic, and we engage in a continuous process of maintaining or adjusting ongoing programs, eliminating programs which have served their purpose, and initiating new programs to meet changing priorities.

We start from the proposition that the principal and unique mission of the NSF is to foster the health of science in the United States. To fulfill that policy, we help scientists search for answers to unresolved questions about nature and its laws and we support disciplinary research needed for future research applications and technology. We seek to maintain a base of scientific competence in all fields of science and to improve our national research capabilities by helping to modernize instrumentation and other facilities. During fiscal year 1972, obligations for scientific research projects, National and Special Research Programs, and National Research Centers amounted to more than $374.2 million, or 60 percent of the total funds obligated by NSF. This represented an increase of $106.8 million over the previous fiscal year.

A scientist engaged in scientific research does so primarily to gain a fuller understanding of the subject studied. His interest may stem from a great variety of reasons. To cite a specific example, one such reason might be the observation of some pattern of periodicity which attracts his attention and curiosity. Some highlights from this year's Annual Report of the NSF will illustrate this particular stimulus to scientific research.

For many years we have known that a variety of changes in the terrestrial upper atmosphere, particularly magnetism, recur regularly. Many such changes come about every 27 days—the solar period of rotation—and are believed to be due to particle beams coming from little-known sources on the sun known as "M-regions." Efforts to trace the particle beams to their solar origin had been unsuccessful until now because of the magnetic fields of the sun's corona and the spiral paths followed by the particles in interplanetary space. From studies completed this year, it now appears that "M-regions" are not correlated with solar activity per se, but are related instead to local changes in the coronal plasma. Above magnetically complex active regions, the lines of magnetic force are closed, while above simple "quiet" regions, the lines of force are more open and allow an outward flow of gas.

Periods of pulsation have also been used to tell us something about distances in space and the problem of galaxy development. Since the early 1900's, astronomers have used pulsating stars to serve as brightness standards of space distance. These stars expand and contract with a rhythmic regularity, and as the dimensions of the star change there are corresponding periodic changes of color and luminosity. In short, the brighter the star, the longer the pulsation period. From this relationship, it is possible to more accurately calculate the distance between the star and the earth. Pulsating stars which have a period of less than a day, called RR Lyrae stars, have been investigated at the Cerro Tololo Inter-American Observatory in Chile, and two discoveries have been made. First, thanks to better access to the southern heavens at the Cerro Tololo observatory where the large Magellanic Cloud can be observed, we have been able to correct previous determinations of RR Lyrae periodicity and improve our estimates of galactic distances. Second, astronomers have found some RR Lyrae stars outside our galaxy with a much smaller spread in their period-luminosity relation than the same types of stars in the Milky Way system where we are located. Since the spread in RR Lyrae stars of our galaxy is attributed to variations in the abundance of elements heavier than helium—an indication of enrichment through successive generations— the smaller spread in the RR Lyrae stars observed outside our galaxy is interpreted to indicate a narrow range of age, i.e., a single generation.

When we turn to periodic motions on earth, we find that notable progress was made last year toward deciphering the complex motions of the sea, particularly the familiar oscillation of the tides. It has now been concluded that the North Atlantic Ocean has a natural vibration period of 14.8 hours. In addition, tidal dissipation rates have been shown to be extremely high, particularly along the continental margin. Knowledge of resonance periods and dissipation rates are vital for oceanographic studies and at the same time are potentially useful for predicting storm tides.

The study of periodicity in space, the upper atmosphere, and oceans described above are all motivated by the desire to understand natural phenomena. But sometimes investigations of periodicity seek more than understanding. They deliberately seek utility, in contrast to the work on tides mentioned before which has a potential practical value only incidental to the main thrust of the research. A good example of utility-oriented research is to be found in NSF-supported investigations of chemical process dynamics which are typical of the petroleum and chemical industries. In this case, the object is not so much to explain regularly recurring phenomena, but to put them to use. By deliberate pulsing and cycling of operating conditions, using specialized computational equipment for modeling and simulation, dramatic improvements in plant performance and efficiency may be possible.

Research, whether basic or applied, is not limited to studies of periodic phenomena, of course. For example, it may be focused on specific areas of societal concern as in the case of the Research Applied to National Needs (RANN) Program. In this program, more direct and explicit consideration than in our programs of scientific research is placed on improving our ability to deal effectively with social and environmental problems and on exploration of technological opportunities that can lead to improvements in economic growth and productivity and to new products and services.

In fiscal year 1972, the RANN Program reached a budget level of $53.8 million—more than 50 percent higher than the previous year when it was established. During this period, the RANN Program represented 9 percent of the total funds obligated by NSF. With these augmented resources, research is being focused across a broad range of projects with principal emphasis on three problem areas. The first is energy, because of its importance to national productivity and economic growth, environmental concerns, and the decline in reserves of preferred fossil fuels. Energy studies supported by RANN have:

- Provided a start toward a complete picture of the present and prospective U.S. energy problem; and
- Identified energy research completed, under way, or still to be done in order to cope with this problem.

Regional environmental systems are a second major focus of RANN because of their importance for the maintenance of life in terms of available natural resources. Although the studies of environmental systems in coastal areas, river basins, urban-rural and semiprimitive areas are aimed at the problems of specific regions, it is expected that the results can also be transferred to similar regions and problems elsewhere.

The third major thrust within the RANN Program relates to municipal systems and services. The population movement from farm to city has been called the silent revolution. As city and suburban populations grow and as people relate to one another through a network of increasing complexity, it becomes ever more urgent to analyze municipal problems systematically. Among these problems are delivery of municipal and social services in communities of varying sizes and in rural as well as urban settings. Here, as in the case of environmental systems, we expect that useful results from one city can be used by other cities faced with similar problems.

RANN is in a youthful phase of development as a program. Synthesis of available information takes time, and the determination of present day concentrations of pollutants and trace compounds in the environment requires patient and careful effort. Predictive models have to be debugged and tested, and policy alternatives assessed. We have some useful results, but much remains to be done.

From the point of view of science education, critical changes have taken place in the social environment. These changes include the movement toward a service-oriented society, the increased desire by greater numbers of students to broaden their educational experiences and career options, and the need to enhance the versatility of our scientific and technological manpower. To cope with these problems, a significant restructuring and revitalization is under way in the Foundation's science education program, with particular emphasis on research and development in science education. Support for NSF education programs, excluding graduate student support, remained fairly steady, amounting to $65.0 million in fiscal year 1972—about 10 percent of the total NSF obligation.

We will continue our long-practiced efforts to improve course content, curricula, and instructional methods. These efforts will concentrate, however, on projects which are problem rather than discipline oriented, and which place special weight on what the student rather than the teacher does. We seek flexibility by giving priority to course and curriculum projects which can be fitted, unit by unit as conditions permit, into existing educational niches. Similarly, we are most interested in the development of new training alternatives at the graduate level, particularly where practical experience can be built into the educational program.

Obviously, benefits can only flow from these efforts if professional educators are informed about them and can choose educational options wisely. Institutes of various kinds are maintained for this purpose, as is the NSF support for improving the initial training for those preparing to become teachers. In order to extend the benefits of new developments as widely as possible, we are also engaged in experimental pilot programs for the improvement of science education on a statewide or school system basis.

Educational experiments are also beginning in a variety of large-scale projects which could result in major changes in the way undergraduate science is taught. With Foundation support, the Illinois Institute of Technology is replacing traditional classroom lectures by a program of project-oriented studies; and at the Worcester Polytechnic Institute, traditional course and degree requirements for an entire college have been eliminated and students are required instead to show competence in a field by completing study projects and undergoing a comprehensive evaluation.

Computer-assisted instruction in the classroom advanced under a vigorous program of development and testing. Such instruction offers promise of both higher quality and less expensive education for many sectors of our society.

As indicated before, our search for an effective balance sometimes requires that programs be eliminated which have served their purpose. Back in 1964, NSF began a program of graduate traineeships to add to the flow of highly talented individuals seeking science degrees. This program—now being phased out—has provided support for more than 35,000 man-years of graduate study.

Two new programs not described in the body of the NSF Annual Report because only preliminary planning and discussion took place during fiscal year 1972 deserve mention. I refer to the programs of Experimental R&D Incentives and National R&D Assessment. Through the Experimental R&D Incentives Program we hope to learn how to help create an environment in which invention and innovation can flourish. To do this we anticipate experimenting —on a small scale—with actual modifications of the institutional or incentive structure involved in technological innovation. Participants in this program will be expected to identify known or suspected blockages of the overall innovation process and to propose experimental changes by which the importance of the blockages can be ascertained and methods of alleviating them tested.

The companion National R&D Assessment Program represents a new effort to meet the needs of policy-makers concerned with how science and technology contribute to the achievement of national goals and well-being in the broadest sense. In this program, national R&D patterns, incentive structures, and decision points will be analyzed and the implications of alternatives will be assessed.

The exchange and accessibility of scientific knowledge is an essential element of the total scientific enterprise, and the Foundation has become a focal point in the Federal Government for science communications activities on both a national and global basis. To meet these new responsibilities—undertaken at the request of the President's Office of Science and Technology—the science information activities of the Foundation have been reoriented to concentrate more closely on the needs of the users.

Leadership responsibilities for NSF take on a variety of forms. The Federal Council for Science and Technology has assigned to the Foundation the responsibility to coordinate, nationally and internationally, the U.S. effort related to the 1973 solar eclipse. This eclipse will be the most favorable for scientific research for the remainder of this century. The most suitable viewing sites are located in northwestern and eastern Africa, and contacts have been made with representatives of foreign countries and international scientific union representatives regarding U.S. needs for studying the eclipse. Through these and other coordinating efforts with interested Federal agencies and private groups, scientists will be able to take full advantage of the approximately 7 minutes of total eclipse in order to observe solar features otherwise masked during full daylight.

In still another remote area, the polar regions, NSF fulfills significant management and coordination responsibilities. Beginning in fiscal year 1972, the NSF has been funding the entire U.S. program in Antarctica, except for icebreaker support. In the Arctic region, where many Federal agencies conduct research programs, NSF chairs an interagency coordinating committee and in different ways coordinates and extends U.S. research efforts in the Arctic.

Sometimes the solution to scientific problems requires concerted efforts on a broad front, as was recognized in the establishment of some of our national and special research programs. An example is the International Decade of Ocean Exploration (IDOE), in which scientists from many universities, often in cooperation with colleagues from other nations, joined forces in an unprecedented long-term study of the forces, the contents, and the influences of the ocean realm. Preliminary results from IDOE studies of the continental margin off the west coast of Africa have identified several large geologic structures with great potential for future petroleum exploitation. In the Ocean Sediment Coring Program, the drilling ship *Glomar Challenger* continued its eminently successful probing of the ocean floor. Among the recent highlights of this operation is the delineation of the complex movements of continents and sea floors in the Indian Ocean area.

Responsibility is not always the result of a formal designation or agreement. Sometimes, as in the case of the establishment of the Materials Research Division, it is the consequence of a series of actions designed to strengthen all parts of an endeavor. As a result of assuming sponsorship of a dozen materials research laboratories (founded by the Advanced Research Projects Agency of the Department of Defense) and the National Magnet Laboratory (founded by the Air Force) and grouping several research support programs from elsewhere in the Foundation, the new division will be responsible for more than 50 percent of the Federal support for materials and solid state research at U.S. educational institutions.

The circumstances under which NSF is called upon and responds to the demands made upon it reveal much about the character and goals of the agency. As mentioned before, the NSF is the sole agency of the Federal Government for which the support of basic research is the principal and most important mission. As such, it has a flexibility which allows it to range broadly, free of the operational limitations which are imposed on other agencies by statute. In carrying out its functions, the NSF emphasizes the concepts of coordination and support. The Foundation gets things done through and with others rather than attempting to do a job by itself. In other words, we try to provide the means whereby something important can be done; and we try to keep people from duplicating the work of others by helping them act together in a concerted way and keeping the channels of scientific communication open.

This statement highlights the cumulative impact of the many changes and activities which have taken place at NSF during the previous year. To summarize these, the NSF has:

- —Strengthened fundamental research to broaden the base of understanding in all scientific fields and disciplines and provided support for important research no longer within the program priorities of other agencies. Particular emphasis has been given to the biological sciences, engineering, chemistry, oceanography, and the social sciences.
- —Expanded research focused on economic, environmental, and social problems. Results of such research will be useful in efforts to improve economic growth and productivity, enhance environmental quality, and improve U.S. capability to deal with social issues.
- —Redirected its science education programs to broaden the spectrum of students benefiting from NSF programs and increase the career options of science graduates.
- —Increased and improved the exchange of scientific knowledge nationally and internationally for the benefit of the United States.

Having done all this and more, we are still confronted with the question of whether a new and better balance has indeed been reached at the end of the year. Obviously, much analysis, careful assessment and judgment, by many people, especially the National Science Board, are involved in the decisions which led to where we are now. But no matter how carefully reasoned, well-intentioned, and sound the decisions might have been, no course of action appears "balanced" to everyone. How then to judge? It is my view that any time we are not investing in a reasonable proportion of basic science, we are neglecting the long-term interests of science and the nation. Any time we are not using to the maximum the scientific knowledge we have already uncovered, we are neglecting the short term. In science education we need to invest a reasonable proportion in curricula, in teaching methods, and in the upgrading of people throughout the education chain. At the same time, we have to prepare for a future with different kinds of students who have a wide range of needs in science education. We have to find ways of providing continuing educational opportunities outside the formal educational system for this country's technologically based society.

Obviously, the application of such criteria does not yield an incontestable, single answer. Those to whom we are accountable will make the necessary judgment. They can do so with the knowledge that we do not stand rigidly on a previously accepted doctrine, nor are we locked into positions that prevent us from adjusting our current state of balance. On the contrary, as this statement has highlighted, we are sensitive to the prospect for change where needed and alert for communications which tell us what the American people want and expect from the scientific community. So, too, are we receptive to judgments from the scientific community as to emerging research areas of great yield. We receive this information from many different sources, and it must be assessed and reconciled.

For these and other reasons, it is necessary that many of our changes be incremental and tailored closely to circumstances. Concurrently, we remain alert for the chance to apply useful leverage through new initiatives which may be useful in the solution of current societal problems. In this way, we can sustain the movement and momentum of the agency toward its statutory goals, and a new balance which is in equilibrium with its changing environment. This, I believe we have done as the record of the Annual Report indicates. This, we will continue to try to do in the future.

Research Project Support Activities

One of the major responsibilities of the National Science Foundation is to support and strengthen fundamental research in all fields of science. The Foundation has provided and will continue to provide strong support for fundamental research in the biological, physical, mathematical, environmental, social, and materials sciences, and in engineering. The Foundation fulfills this responsibility by supporting efforts of individual scientists and engineers in their search to resolve scientific questions concerning basic life processes; natural laws and phenomena; complex factors influencing man's environment; and the physical, psychological, and other forces determining the individual behavior of man as well as the collective behavior of his societies. Within NSF, the Research Directorate has the principal role in providing the dynamics and organization of this support. There are two principal mechanisms by which it does this:

- Grants to academic institutions in support of individuals or small groups of scientists doing research considered to have outstanding potential for the development of new scientific knowledge.
- Grants in support of programs such as the International Biological Program and the Global Atmospheric Research Program. (These programs are described with other national programs on pages 36-39).

Support is also provided to assist in:

- Obtaining specialized research equipment, instrumentation, and research facilities.
- Defraying the costs of travel for individual scientists attending selected scientific conferences.
- Convening conferences and symposia.
- Supporting dissertation research in the social sciences and certain other sciences involving extensive field work.

RESEARCH PROJECT SUPPORT

The support of basic research in the United States has gone through significant adjustments in the past few years as a consequence of changing national priorities. During fiscal year 1972, by virtue of a special increase in its appropriation, the NSF was able to respond to this problem by increasing its support of research by an appreciable fraction of the amount cut back by other agencies. By this action, the executive branch and the Congress moved in concert to minimize the adverse impact upon the nation's strength in the basic sciences of a number of program changes by agencies whose support of basic research must, of necessity, be kept rather closely attuned to shifting mission requirements. This adjustment was made in all affected science disciplines.

In fiscal year 1972, the Foundation awarded 5,658 grants amounting to $242.5 million for the support of individual research projects. Comparable figures for fiscal year 1971 were 4,495 grants for a total of $180.3 million. The distribution, number, and amount of grants according to field of science for fiscal years 1970, 1971, and 1972 are shown in table 1. Grants were awarded to 471 institutions, including 326 colleges and universities, in all 50 States, the District of Columbia, and Puerto Rico; 94 percent of the funds went to academic institutions. Of these, 232 received two or more research grants, and 130 received $200,000 or more. Table 2 shows the average distribution in fiscal year 1972 for approved cost items on the 5,658 research grants.

SPECIALIZED RESEARCH FACILITIES AND EQUIPMENT

In fiscal year 1972, the Foundation awarded $6.0 million to institutions to assist in the purchase of specialized facilities and equipment in biology, astronomy, earth and atmospheric sciences, physics, chemistry, engineering, materials sciences, and the social sciences. (Computing and oceanographic facilities are discussed in the chapter on National and International Programs.) Table 3 shows the distribution of funds over a 3-year period. The nature of this support for specialized equipment and facilities is illustrated by the following examples.

Table 1
Scientific Research Projects
Fiscal Years 1970, 1971, and 1972

(Dollars in millions)

	Fiscal year 1970		Fiscal year 1971		Fiscal year 1972	
	Number	Amount	Number	Amount	Number	Amount
Physics						
Elementary Particle Physics		$11.24		$11.60		$13.69
Nuclear Physics		6.46		9.42		10.92
Atomic, Molecular & Plasma Physics		2.72		2.75		3.20
Theoretical Physics		3.34		2.72		3.27
Gravitational		- 0 -		- 0 -		1.25
Subtotal	245	28.18[1]	290	26.49	267	32.33
Chemistry						
Synthetic Chemistry		4.05		4.27		5.00
Structural Chemistry		2.80		3.07		3.01
Quantum Chemistry		3.40		3.50		4.05
Chemical Dynamics		3.58		3.52		4.10
Chemical Analysis		1.71		1.81		2.75
Chemical Thermodynamics		1.86		1.77		2.25
Chemical Instrumentation		- 0 -		1.70		1.69
Subtotal	449	17.40	488	19.64	593	22.85
Astronomy						
Solar System Astronomy		.58		.45		.50
Stars and Stellar Evolution		1.45		1.59		1.77
Stellar Systems and Motions		.77		.52		.57
Galactic and Extragalactic Astronomy		1.26		3.17		3.96
Astronomical Instrumentation and Development		1.74		.94		.95
Subtotal	108	5.80	135	6.67	131	7.75
Mathematical Sciences						
Classical Analysis and Geometry		4.34		2.22		2.61
Modern Analysis and Probability				2.36		2.62
Algebra		4.49		2.49		2.98
Topology and Foundations				2.22		2.27
Applied Mathematics and Statistics		3.83		3.06		3.27
Special Projects		- 0 -		.59		- 0 -
Subtotal	439	12.66	535	12.94	693	13.75
Biological Sciences						
Cellular Biology		8.68		8.92		11.80
Ecology and Systematic Biology		8.60		8.86		10.21
Molecular Biology		9.76		9.95		12.45
Physiological Processes		9.53		8.89		9.93
Neurobiology		- 0 -		4.05		4.40
Psychobiology		4.30		3.60		4.00
Subtotal	1,072	40.87	1,369	44.27	1,620	52.79
Atmospheric Sciences						
Aeronomy		1.69		2.35		3.19
Meteorology		3.95		4.73		5.33
Solar-Terrestrial		2.28		2.36		2.90
Subtotal	118	7.92	143	9.44	211	11.42
Earth Sciences						
Geology		1.42		1.64		1.75
Geochemistry		3.07		3.05		3.72
Geophysics		3.36		3.43		3.91
Subtotal	169	7.85	225	8.12	253	9.38
Oceanography						
Physical and Chemical Oceanography		2.07		2.70		3.95
Submarine Geology and Geophysics		3.18		3.36		4.12
Biological Oceanography		3.66		3.92		4.38
Subtotal	218	8.91	235	9.98	268	12.45
Engineering						
Engineering Chemistry		2.83		3.04		7.37
Engineering Energetics		2.86		2.79		
Engineering Mechanics		6.55		5.77		10.12
Electrical Sciences and Analysis		- 0 -		1.48		6.89
Special Engineering		1.17		1.02		- 0 -
Subtotal	463	16.70[2]	385	14.10	634	24.38

Table 1—Continued
Scientific Research Projects
Fiscal Years 1970, 1971, and 1972
(Dollars in millions)

	Fiscal year 1970		Fiscal year 1971		Fiscal year 1972	
	Number	Amount	Number	Amount	Number	Amount
Social Sciences						
Anthropology		$3.47		$ 3.56		$ 3.80
Economics		4.35		4.56		5.20
Economic and Social Geography		- 0 -		.65		.80
Sociology		1.68		1.21		2.10
Social Psychology		1.68		1.42		2.10
Political Science		1.19		.77		1.48
History and Philosophy of Science		.83		.76		.87
Special Projects		1.74		2.10		2.77
Law and Social Science		- 0 -		.69		.90
Geography		.48		- 0 -		- 0 -
Social Indicators		- 0 -		1.94		2.05
Subtotal	459	15.42	484	17.66	613	22.07
Materials Research						
Engineering Materials		- 0 -		4.01		6.58
Solid State and Low Temperature Physics		- 0 -		5.72		9.66
Solid State Chemistry and Polymer Science		- 0 -		.93		2.07
Materials Research Laboratories		- 0 -		- 0 -		12.80
National Magnet Laboratory		- 0 -		.40		2.28
Subtotal	- 0 -	- 0 -	206	11.06	375	33.39
Total	3,790	$161.71	4,495	$180.37	5,658	$242.56

[1] Includes Solid State and Low Temperature Physics of $4.42. [2] Includes Engineering Materials of $3.29.

Table 2
Scientific Research Projects, Average Distribution of Funds by Type of Expenditure
Fiscal Years 1970, 1971, and 1972

	Fiscal year 1970		Fiscal year 1971		Fiscal year 1972	
	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total
Professional Personnel						
Faculty	$ 6,758	15.4	$ 6,560	15.0	$ 6,194	14.1
Research Associates	2,940	6.7	2,668	6.1	2,987	6.8
Research Assistants	6,275	14.3	5,510	12.6	4,877	11.1
Other Professional	2,150	4.9	2,274	5.2	2,065	4.7
Total Professional Personnel	18,123	41.3	17,012	38.9	16,123	36.7
Other Personnel	3,467	7.9	3,499	8.0	3,383	7.7
Fringe Benefits	1,492	3.4	1,618	3.7	1,757	4.0
Total Salaries and Wages	23,082	52.6	22,129	50.6	21,263	48.4
Permanent Equipment	2,677	6.1	2,756	6.3	2,724	6.2
Expendable Equipment and Supplies	3,028	6.9	3,149	7.2	2,900	6.6
Travel	1,273	2.9	1,356	3.1	1,318	3.0
Publication and Printing	658	1.5	612	1.4	615	1.4
Computing Costs	1,360	3.1	1,356	3.1	1,186	2.7
Other Costs	2,019	4.6	2,536	5.8	3,778	8.6
Total Direct Costs	34,097	77.7	33,894	77.5	33,784	76.9
Indirect Costs	9,786	22.3	9,840	22.5	10,148	23.1
Total Average Grant	$43,883	100.0	$43,734	100.0	$43,932	100.0

Table 3
Specialized Research Facilities and Equipment
Fiscal Years 1970, 1971, and 1972
(Dollars in millions)

	Fiscal year 1970		Fiscal year 1971		Fiscal year 1972	
	Number	Amount	Number	Amount	Number	Amount
Astronomy	5	$ .190	3	$ .250	4	$ .253
Atmospheric Sciences	4	.199	5	.290	7	.287
Biological and Medical Sciences	11	.918	22	.904	24	1.214
Chemistry	63	1.697	58	1.700	40	1.673
Earth Sciences	3	.103	2	.121	4	.100
Engineering	28	.600	30	.752	31	.625
Oceanography		[1]	1	.067	5	.100
Physics	12	2.499	5	1.444	4	.949
Social Sciences	1	.298	6	.272	6	.386
Materials Research	----	----	----	----	17	.425
Total	127	$6.504	131	$5.800	142	$6.012

[1] Included in National and Special Research Programs in Fiscal Year 1970.

As a result of growing enthusiasm by researchers in several fields other than physics to use synchrotron radiation in their experiments, existing facilities for such radiation use were expanded. These facilities provide a unique source of intense and continuum X-rays which are of significant value to solid-state physicists, chemists, and atmospheric scientists, and which promise in the near future to be of use to biologists and radiologists as well. At this type of specialized facility, such varied projects are carried out as the study of photoemission spectra of metals with chemisorbed molecules (important in understanding the mechanism of chemical action on surfaces of all types), exciton fluorescence measurements on aromatic compounds, and photoabsorption cross section measurements for important atmospheric gases.

Another area where equipment and facilities were improved is in the field of noise research. NSF grants will make possible continued and expanded investigations in acoustical attenuation, the effect of transient noise on the auditory system, and research on environmental noise created by various sources such as residential air conditioners, diesel engines, jet engines, turbines, fans, air-moving devices, compressors, and traffic noise. This area of research has been increasing in importance as population density and societal stresses increase and environmental issues gain priority in public attention.

A low temperature hydraulic flow facility at the University of Iowa, constructed 2 years ago, has been continuously used with outstanding results on a number of basic and applied studies involving various hydraulic engineering characteristics of ice and ice formation. One study probed the stability of turbulent flows past freezing and melting ice boundaries and the attendant formation of ice ripples and their effects on flows in ice-covered rivers. A part of this research won the international 1971 Straub prize for the year's outstanding hydraulics Ph.D. thesis. Another study investigated the mechanics of ice jams and the conditions under which fragmented ice accumulations become unstable, giving rise to channel blockage and flooding. A project of environmental interest is a study of the effects on river ice of the thermal effluent from a nuclear power plant. The length of the Mississippi River that will be kept ice-free by this effluent is being investigated analytically.

MATHEMATICAL AND PHYSICAL SCIENCES

Vigorous and exciting progress characterize the four areas—physics, chemistry, astronomy, and mathematics—that comprise the Mathematical and Physical Sciences Division. These traditional disciplines are highly developed in technique, theory, and patterns of thought. They continuously exchange new knowledge, techniques, ideas, and problems among themselves and also enlarge, enrich, and systematize their interactions with other areas of science and technology. The support patterns in these fields have been strongly perturbed, however, during recent years by the withdrawal of many other Federal agencies from the support of such research.

The *physics* research program spans natural phenomena from subatomic particles to the forces that shape the universe. Continuous advances in understanding these phenomena result in a steady transfer of knowledge to chemistry, the environmental sciences, engineering, the life sciences, and other areas directly concerned with finding ways to improve man's ability to live with and manage his surroundings. A reflection of this transfer was the assignment in 1972 of the Physics Program's work in solid state and low temperature physics and corresponding components of theoretical physics to the new Division of Materials Research, thereby relating knowledge from the forefront of physics research to development of new materials and materials processing techniques.

Basic physics research is a source of long-range technological progress. For example, research into properties of the atomic nucleus has led to the formation of an entire new technology—nuclear power—which is already a billion-dollar industry and may, within a few decades, alter our entire approach to energy requirements. The modern electronics, communication, and computer industries are grounded in basic physics. Physics contributes to improved cancer radiation therapy through the use of new types of radiation, contributes to developing new sources of power to meet growing demands for energy, and contributes to improved technologies in such areas as lasers, magnetic materials, and spectrometry. The technological payoff from basic physics research will continue.

The *chemistry* research program increases our knowledge of the composition, structure, and mutual interconversion of substances. It seeks ways of predicting, in general, which atomic or molecular arrangement will produce a desired property, predicting the optimum sequence of reactions to produce a desired molecule, and understanding the rates of chemical reactions.

The areas of modern chemical research are interactive: Advances in one area are closely tied to advances in the others. For example, methods of chemical analysis and quantitative measurements, usually accomplished with modern sophisticated instruments, are indispensable to the solution of nearly any chemical problem. Much of the progress made in understanding molecular processes rests on the availability of instrumentation that permits the separation and analysis of complicated mixtures or that measures the effects of subtle changes in molecular properties.

Another area of major importance is the development of an understanding of the mechanisms by which catalysts influence the rates of chemical reactions without permanent change to the catalysts. NSF not only supports ongoing research, but also research that probes new areas of opportunity that may lead to commercial application.

Research in *astronomy* deals with methods and equipment to increase our understanding of the objects and phenomena in the universe, the laws that govern them, and the relationships among matter, time, and space. Some of these objects are so remote that they can be studied only by means of electromagnetic radiation and cosmic particles coming from them and caught with instruments on the earth. These instruments, in short supply and exceedingly expensive to build, have benefited in recent years by technological developments that have increased the ability of astronomers to record more data using new instrumentation on existing telescopes. The need for Federal support of astronomy is large in comparison to many other fields of science because astronomy, though crucial in elucidating theories concerning physical laws, is not usually directly applicable to problems that would merit industrial or non-Federal support. NSF supports about 90 percent of the total U.S. effort in ground-based astronomy, the balance coming from private and State sources.

The program in *mathematical sciences* supports the creation of new techniques, understanding of mathematical structures already extant and the relations between them, and the construction of mathematical models of physical, biological, or social phenomena and their application to the world in which we live. As we develop more complex technologies in which elements of the social and biological sciences are intermingled with those of the physical and engineering sciences, mathematics will play an increasing role. The applications of mathematical research are generally not immediate and, when they are made, are apt to be widely diffused first into other sciences and then into technology.

The recent past in mathematics has been characterized by increasing abstraction and generalization, with the effect of revealing unsuspected kinships and confluence among traditional mathematical disciplines. The result has been the creation of tools of unprecedented power for attacking problems of great difficulty. For example, the mathematical tools for a sophisticated theory of guidance of many kinds of vehicles, machines, and industrial processes have been made available through research in analysis and topology, and have resulted in a burgeoning of research in nonlinear ordinary differential equations. This research has also been responsible for the development of those parts of applied mathematics known as control theory, optimization theory, and differential "games."

Examples of a few important research projects in the mathematical and physical sciences are described on the following pages.

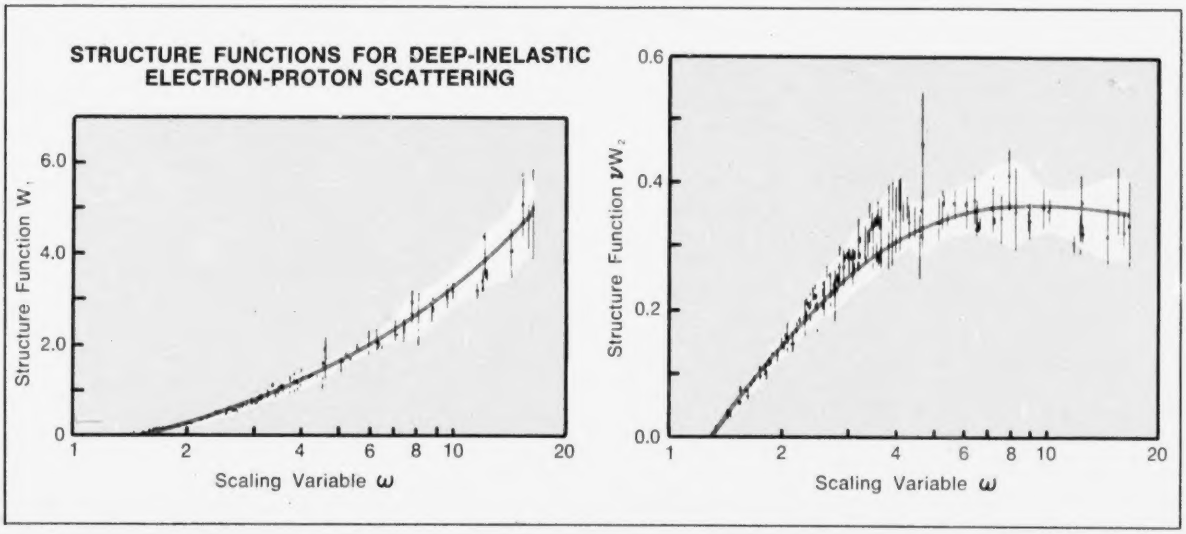
PHYSICS

Scaling and Partons—A Substructure for the Proton?

One of the most important and stimulating findings in particle physics in recent years is the discovery of scale invariance—or "scaling." Briefly, the scaling property implies that certain phenomena involved in reactions of elementary particles have a very simple mathematical representation, depending only on ratios of a few measured quantities. These ratios, which have no dimensions (like miles per hour), are, in a sense, analogous to the more familiar dimensionless numbers, such as the Reynolds number in hydrodynamics which relates turbulent to laminar flows, or the Mach number in aerodynamics, which characterizes the kinds of shock waves that occur in supersonic flow.

Initially suggested theoretically, scaling was first observed in the deep inelastic scattering of electrons on protons (in which the proton is broken apart by the deep-probing electron) at the Stanford Linear Accelerator Center (SLAC), and subsequently confirmed in more detailed measurements at the Cornell Electron Synchrotron. In these experiments, some of the kinetic energy of the incident electrons is converted to mass, which is ejected in the form of one or more elementary particles in addition to the struck proton. A large number of physical variables are necessary to describe the resulting complex multi-particle final states in such reactions. The first scaling experiments measured a quantity called the "inclusive cross section," which is the probability of the electron scattering through a given angle. To determine it, only the incident and outgoing electron need be dealt with, and all of the additional particles can be ignored. This cross section is computed with the use of two so-called "structure" functions which depend on the energy lost by the incident electron and the momentum transferred by that electron to the target proton. But when the structure functions are calculated for grossly different values of both energy loss and momentum transfer, their results fall along a smooth curve indicating that, over a wide range of energy and momentum transfers, these structure functions depend only on a dimensionless ratio of the two variables.

The remarkable simplicity of this behavior may have profound implications for understanding the structure of the proton itself, and a number of models have been adduced to explain these results. In one, the so-called "parton model" of R. P. Feynman at the California Institute of Technology, the nucleon (neutron or proton) is envisioned as a noninteracting gas of fundamental particles called "partons." Deep inelastic scattering can be described as scattering of the electrons from these pointlike partons. This interpretation is reminiscent of



These experimental measurements show the "structure" functions that determine the inclusive cross section for deep inelastic scatterings. Adjacent points on these graphs are measured at grossly different values of energy and momentum transfer, but at neighboring values of their dimensionless ratio—the scaling variable ω. The fact that these points define approximately smooth curves rather than scatter uniformly over the graph is a verification of the scaling hypothesis.

Rutherford's work at the turn of the century, when his study of the behavior of the scattering of alpha particles from heavy atoms led him to conclude that these atoms were made up of diffusely distributed clouds of electrons surrounding a pointlike, positively charged nucleus. Determining specific details of the deep inelastic process will answer a host of questions about the partons if they really do exist, and further experimental studies are going on at both SLAC and Cornell.

In addition, deep inelastic scattering experiments will shortly be extended to a new energy domain at the National Accelerator Laboratory in Batavia, Ill., where experiments involving beams of elementary particles known as muons (instead of electrons) will investigate scaling behavior in regions of energy and momentum transfer an order of magnitude larger than those accessible at SLAC and Cornell. One of the first such experiments, to be performed jointly by NSF-supported groups from Michigan State, Cornell, and the University of California, San Diego, will scatter muons from heavy nuclei and investigate a wide range of variables. A second, more elaborate experiment, by a Chicago-Harvard-Oxford collaboration, will study a somewhat smaller kinematical range, but will use a liquid hydrogen (i.e., proton) target, and make a detailed study of all the outgoing particles as well.

Gravitational Radiation Revisited

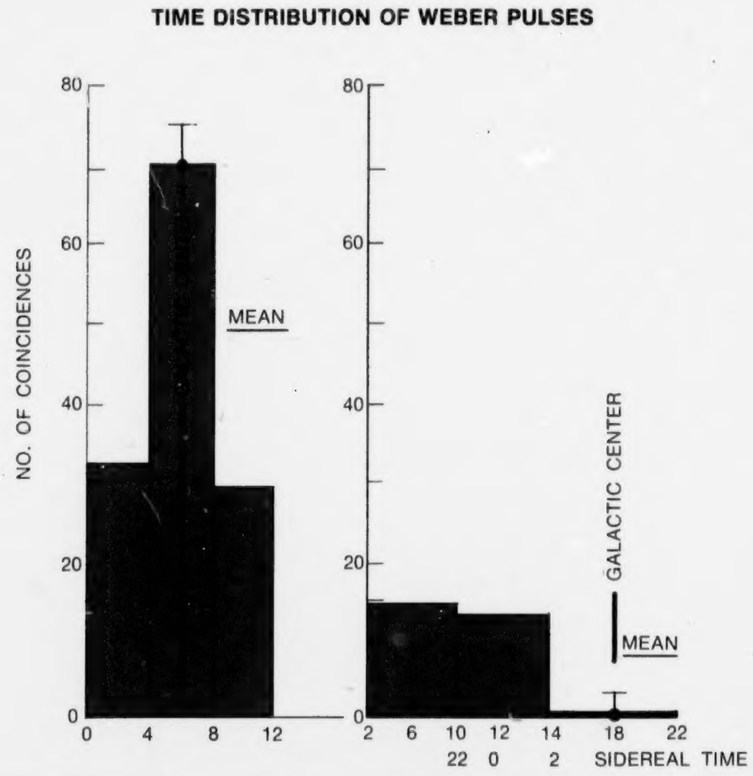
Three years ago, Joseph Weber of the University of Maryland announced the detection of events that he identified with pulses of gravitational radiation from some distant source. Although this interpretation of his data was greeted initially with skepticism by many members of the scientific community, Dr. Weber has continued to refine his techniques during the intervening years. The additional observations that he has been able to obtain with these improvements are consistent with the idea that he is indeed detecting gravitational radiation, although they pose grave difficulties for theories of the sources of this radiation.

Dr. Weber's initial experiment consisted of looking for anomalous excitations of vibrations of two 1-1/2-ton aluminum cylinders, one located at College Park, Md., and the other at the Argonne National Laboratory outside Chicago. A count was made of the number of times both cylinders were excited essentially simultaneously (an event termed a "coincidence"), and it was found that these coincidences occurred much more frequently than could be explained on the hypothesis that the bars were being excited by random thermal oscillations. Subsequent experiments have effectively ruled out the possibility that these signals are due to the earth's seismic activity, long wavelength electromagnetic disturbances, or cosmic rays—the three most popular alternative explanations. In addition, the directional sensitivity of the cylinders indicated a signal source at either the galactic center or a point diametrically opposed to the galactic center, not far from the Crab nebula. In the past year, Dr. Weber has instrumented a new disk-type of detector, which has a directional response different from the cylinder detectors. This detector, when run in coincidence with one of the old cylinder detectors, is capable of removing the previous ambiguity of the source direction. New experiments point to a source of gravitational radiation at the center of our galaxy, rather than the anti-center.

These remarkable observations have stimulated intense activity in many segments of the scientific community. Theoretical physicists have pointed out that if the events are gravitational in origin, and if their source is located in the center of the galaxy and radiating energy with equal strength in all directions, then enough mass must be converted into energy in the form of gravitational waves near the galactic center to have a noticeable effect on the motions of clouds of hydrogen gas near the solar system. Radio astronomers have not detected such motions, however, and this has led one group of theorists, under the direction of Charles Misner (also at Maryland) to suggest a kind of gravitational synchrotron radiation as a possible source mechanism. In this theory, gravitational radiation from a very rapidly accelerated massive object orbiting near the galactic center would beam its radiation predominantly into the plane of the galaxy. Although this beaming would relieve the stringent energy loss requirements mentioned above, no one has yet proposed a convincing picture of how the radiating masses could get into their orbits.

On the experimental side, groups are setting up apparatus to confirm Dr. Weber's results, including one in the U.S.S.R., one in Germany, two each in Italy and the United Kingdom, and one in Canada. In the United States, the Foundation is supporting two efforts in addition to Dr. Weber's. One detector system at the University of Rochester is quite simi-

Physicist Joseph Weber is here shown with his disk detector. This detector is least sensitive to the kind of gravitational radiation predicted by Einstein's theory when its flat face is perpendicular to the direction of the radiating source.



Original experiments to detect gravitational radiation recorded coincident "events" measured by cylinders at two widely separated locations. They revealed a source of radiation at either the center or anti-center of our galaxy (left). (The earth is essentially transparent to gravitational radiation, so the data are combined into half a day's time.) Recent experiments (right) using one cylinder and one disk detector (which is least sensitive to radiation when its flat face is pointed towards it) show the fewest coincidences when pointing toward the galactic center—confirmation that the center is the source of the radiation.

lar to Dr. Weber's, and will be run in coincidence with a detector being constructed at the Bell Telephone Laboratories. Superconducting detectors to achieve maximum isolation from all sources of thermal noise will be run at Louisiana State University and Stanford University. Through collaborative efforts such as these, physicists in the next few years hope to gain new insights into the nature of the surprising phenomenon discovered by Dr. Weber, which, if it is not gravitational radiation, is likely to be even more significant.

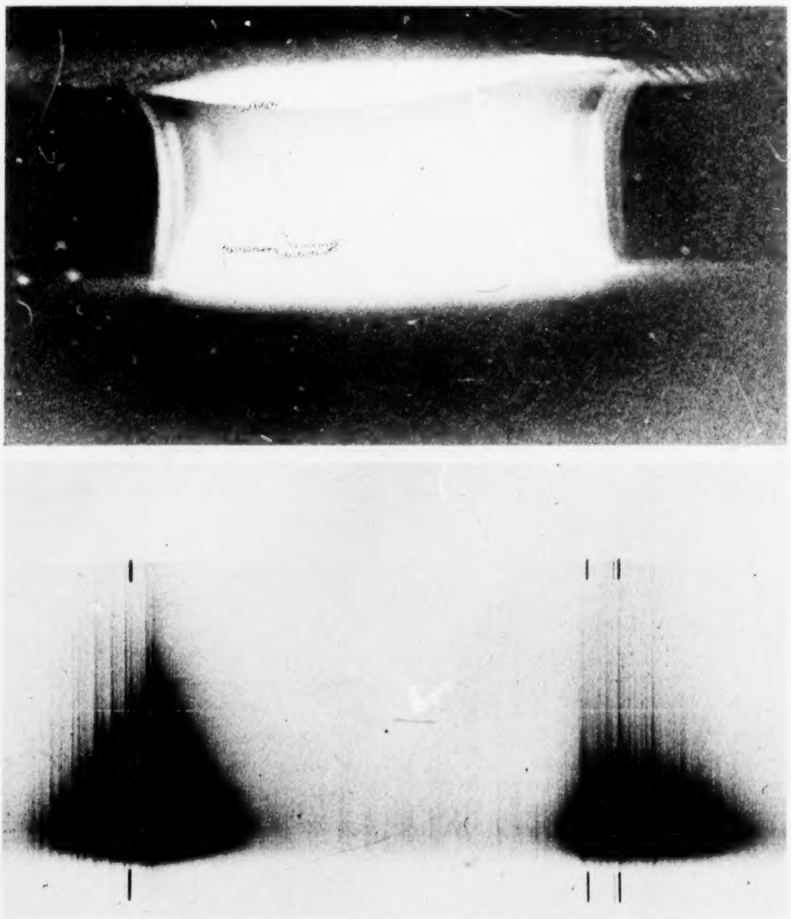
CHEMISTRY

Chemistry and Combustion

What happens in flames is a matter of great practical concern. From the simple hydrogen-oxygen flame, now being reexamined as a possible major source of energy, to the complex combustion of wood, chemists are devoting increasing effort to trying to understand the details of the combustion process. This work is possible as a result of instruments and techniques that have become available in the past two decades for study of the extremely fast and energetic processes that occur in flames.

Foundation grantees are working on many projects to understand these processes. Thomas Vickers of the University of Florida is studying the changes in light absorbed and emitted when trace amounts of heavy metals are present in hydrogen flames. At Pennsylvania State University, Howard Palmer has recently observed light from an excited form of sulfur dioxide for the first time when carbon disulfide or carbon oxysulfide is burned in oxygen. At the State University of New York at Binghamton, Walter Kaskan may provide information useful in assessing the potential of ammonia as a fuel from his measurements of the formation and destruction of nitrogen oxide in ammonia flames.

In those examples, flames are being studied directly. It is possible, however, to learn a great deal about flames by generating the reactive species present in flames by processes other than combustion and studying their reactions. For example, direct studies have shown that many flames contain a number of reactive fragments, including oxygen and hydrogen atoms and hydroxyl radicals (the product from combination of one hydrogen and one oxygen atom). These species can be produced in a number of ways. Frederick Kaufman at the University of Pittsburgh simply heats hydrogen gas with a tungsten filament to create hydrogen atoms; he then studies their reaction with each other in the presence of other gases such as carbon dioxide, water vapor, or methane. At Illinois Institute of Technology, David Gutman uses microwave or radiofrequency discharges to dissociate oxygen molecules into oxygen atoms. A stream of these atoms is then made to collide with a crossed beam of "fuel," such as acetylene, and the unstable products of the collisions are detected. This method has already been used to show that the inferences about these products from previous experiments in which



In this reaction of hydrogen gas containing methyl borate burning in air, the brighter low region is the flame or reaction zone, and the middle and upper region is the burned gas (the metal screen above the flame gives hydrodynamic stability). The vertical streaks on the sides are clouds of condensed boric oxide particles and mark the hot/cold boundary. A spectogram of the flame shows the light emitted by the boric oxide bands, with the brighter portion of the spectrum at the bottom in the flame zone and the darker portion above in the burned gases. (Photo by Walter Kaskan, SUNY-Binghamton)

they could not be detected directly were wrong. Ultraviolet light can also cause dissociation of molecules into atoms or larger molecular fragments, both in the laboratory and in the atmosphere. In fact, the work of both Drs. Kaufman and Gutman is equally important in understanding smog and upper atmosphere chemistry as it is for explaining combustion.

Another technique that produces temperatures, fragments, and light emission very similar to flames is to pass shock waves through a mixture of gases. Dr. Gutman also used this method to study the acetylene-oxygen reaction. In the first experiment, the crossed beams, he learned what unstable fragments are initially formed. He was then able to deduce something about how fast they form and react from the nature of the light emitted from the shock tube. Ralph Kern at Louisiana State University is now using a modification of the shock tube technique to learn how methane decomposes when it is heated. Among other things, it turns out that one of the intermediate products is acetylene, which immediately links this study with Dr. Gutman's.

The reactions discussed so far were intentionally chosen by the investigators to be as simple as possible. Still, the acetylene-oxygen reaction probably involves at least 20 intermediate compounds before the final stable products, water and carbon dioxide, are formed. The techniques being used in these relatively simple combustions would produce hopelessly complicated results if they were applied to a process such as the combustion of the cellulose of which cotton consists. Yet, understanding this process is at least as important as knowing how acetylene burns. The approach being used by Fred Shafizadeh at the University of Montana, and at the University of California's Statewide Air Pollution Research Center in Riverside, is called pyrolysis. This involves heating cellulose below flame temperatures and/or in the absence of oxygen and collecting and identifying the gaseous products formed. At the California laboratories, cotton treated with sugar containing radioactive carbon produces cellulose containing radioactive "labels." Pyrolysis of this material will help determine the exact source of the carbon monoxide and carbon dioxide produced.

None of the experiments discussed here is spectacular in itself. Yet, all of them, and a much larger body of research on the chemistry of reactive fragments, are providing a base of scientific understanding which is crucial to the solution of the practical problems of fire prevention and air pollution, as well as a host of other problems of economic and environmental importance.

Potential Surface for the $F + H_2$ Reaction

Powerful theoretical techniques are now being brought to bear on reactions similar to those which occur in combustion. An important goal is the prediction, from first principles, of chemical reaction rates, and a great deal of effort has been expended on this problem since the early 1930's. Basically, quantum mechanics is employed in the calculation of points on a "hill-and-valley-like" surface representing the potential energy of a system of atoms and molecules in a particular configuration. Low regions shaped somewhat like narrow valleys, representing relatively low potential energy, correspond to compounds. The passage of a point from one valley over a saddle point (or pass) into another valley represents a chemical reaction, and the shape of the surface determines the rate of the reaction and the energy disposition among the products.

The surface for the system of three hydrogen atoms (the same system being studied experimentally by Dr. Kaufman) is the simplest to treat theoretically. It has received extensive study, from which principles useful in more complex situations have emerged. Development of computational techniques and the availability of high-speed computers now makes possible reliable calculations for systems containing larger atoms.

Henry F. Schaefer III, of the University of California, Berkeley, with the aid of a Foundation grant and in collaboration with several other scientists, has recently carried out calculations for the potential energy surface for the fluorine plus hydrogen molecule system. The chemical reaction $F + H_2 \rightarrow FH + H$ has been studied experimentally by a number of techniques related to those used by Drs. Kaufman and Gutman, and fairly detailed information is available about the reaction dynamics.

In preliminary work, about 350 individual calculations were carried out, each referring to a particular arrangement of the three atoms. A great deal of information was obtained about the potential surface and about the usefulness of various theoretical approaches. It was found that the minimum energy path for the reaction involved an arrangement in which the F-H-H atoms lie along a straight line. Further refinements produced a potential surface which is thought to correspond fairly closely to reality and is considered to be of chemical accuracy. The barrier height (which represents the energy difference between the saddle point and the separated reactants) and the exothermicity (the energy released when the reaction occurs) agree quite well with experimental quantities. It is expected that this potential surface, calculated from first principles, will be useful for dynamical studies (classical trajectories, semiclassical and quantum treatments) that will allow comparison of additional theoretical results with information obtained by experiment. Dr. Schaefer is also applying this kind of analysis to reactions involving hydrogen and oxygen species, which should provide a theoretical base with which to compare and refine the experimental studies of simple flames.

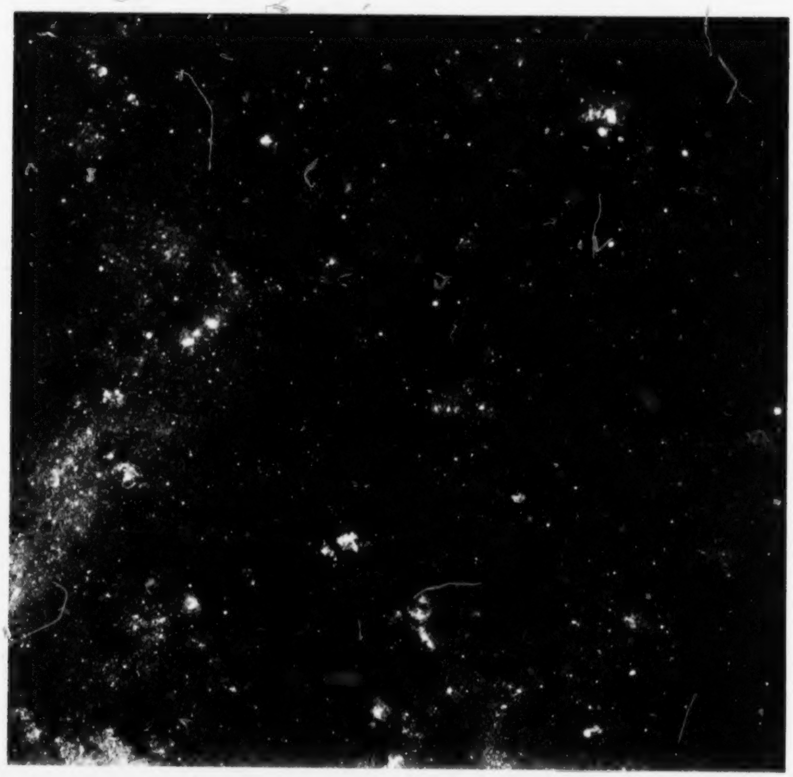
ASTRONOMY

Standard Candles

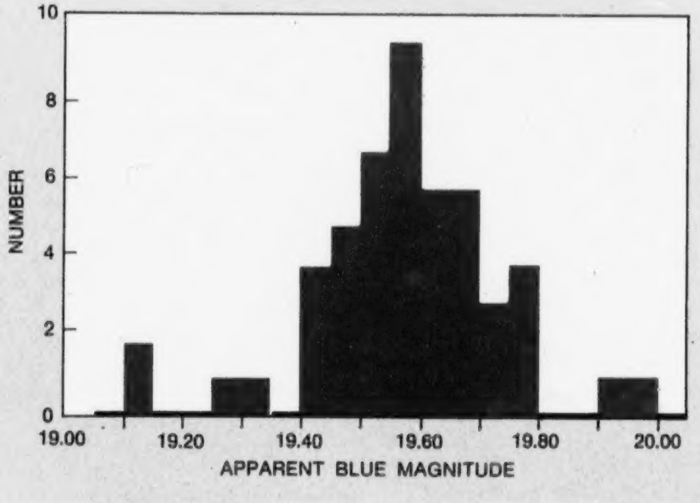
One of the most difficult and yet one of the most fundamental observational problems which astronomers must solve is that of identifying stars of known intrinsic brightness to serve as basic indicators of distance to the systems in which they are found. Over the past half century pulsating variables (e.g., Cepheids) have been these standards. Early research indicated a linear relation between intrinsic brightness and period of pulsation, though upon closer inspection the relation has required extensive modification. Each change has produced alterations in the distance scale of our own and distant galaxies.

Variable stars that pulsate in less than a day, the RR Lyrae stars, have been the subject of two observational programs at the Cerro Tololo Inter-American Observatory (CTIO). John Graham, a CTIO staff member, is now completing a study of 52 RR Lyrae stars in the Large Magellanic Cloud, a small satellite of our own galaxy. Dr. Graham has discovered that the RR Lyrae variables in this nearby companion form a very homogeneous group having a much smaller spread in their period-luminosity relation than is found for the same types of stars in the main Milky Way system, where we are located. The dispersion found in our own galaxy is attributed to variations in the abundance of elements heavier than helium. Dr. Graham's observations, therefore, indicate that the RR Lyrae stars in the Large Cloud have a very small range in heavy-element abundance. His result is further interpreted as meaning a narrow range of age, i.e., a single generation, for stars in the Large Magellanic Cloud, as opposed to the several generations present in the Milky Way. Each successive generation is richer than the preceding one in carbon, nitrogen, oxygen, and heavier metals because nuclear reactions in older stars slowly fuse these elements from hydrogen and helium, enriching the raw material for new stars.

A similar study of RR Lyrae stars in our own Milky Way system has been made jointly by F. D. A. Hartwick and Graham Hill, guest investigators at CTIO, and James E. Hesser of the CTIO staff. Although the very central regions of our galaxy are effectively blocked from our view by heavy interstellar obscuration, there is a small, relatively clear region toward the galactic center in which Walter Baade discovered over 100 RR Lyrae stars many years ago. Using these objects as "standard candles," Dr. Baade was able to make an estimate of the distance to the center of our galaxy and thus set the scale for all galactic structure studies. The region studied by Dr. Baade is in the southern sky and he could observe it only for a very short time, since it never rises more than about 20° above the horizon at the Mt. Wilson Observatory in California. Dr. Hesser and his colleagues have demonstrated that in



The nearest neighbor of our own Milky Way galaxy, the Large Magellanic Cloud, passes nearly overhead at the Cerro Tololo Inter-American Observatory in Chile. Excellent observations of its constituent stars can be made there, as the chart below, the distribution of RR Lyrae stars, shows. The narrow width of the distribution indicates that these stars formed from the interstellar medium at nearly the same time, as opposed to the several generations in the Milky Way. (Photo by John Graham, CTIO; chart by Kitt Peak National Observatory)



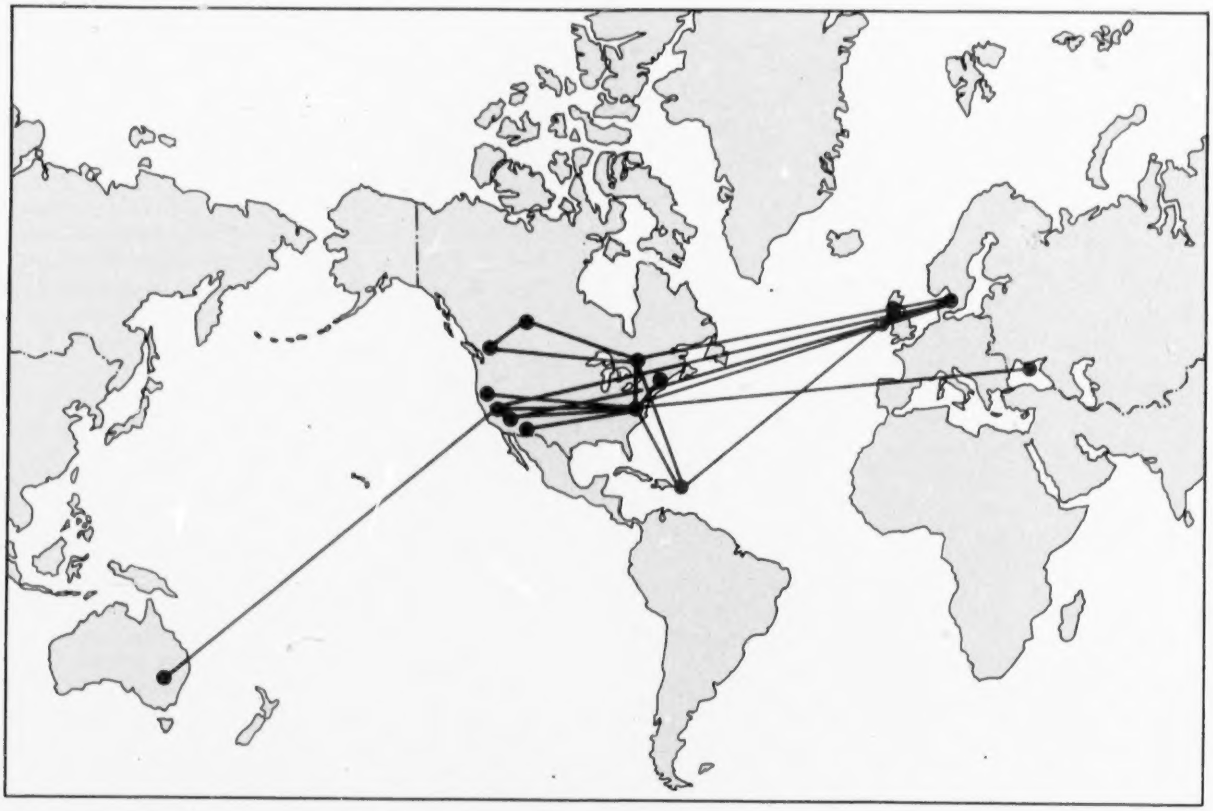
84 percent of the 38 variables checked by the observers in Chile, the observing conditions imposed on Dr. Baade at Mt. Wilson, coupled with the limitation that the periods of pulsation of RR Lyraes are some fraction of a day, led to erroneous determinations of periods. New determinations of the characteristics of these stars—their periods and metal abundances—will lead to an improved estimate of the size of our galaxy.

Very Long Baseline Interferometry

Digital Very Long Baseline (VLB) interferometry is an observing technique used at the National Radio Astronomy Observatory (NRAO) and certain other observatories. Recordings of a celestial radio source are made simultaneously at two or more widely separated sites, using atomic clocks for synchronization. Later, intercomparison of the recorded data from all sites involved permits construction of a model of the spatial structure of the radio source with extremely high angular resolving power.

One of the most exciting finds to come from the new technique is the discovery of "super-relativistic" expansion in radio sources. During a series of transcontinental observations made from 1970 to the present, the visibility patterns of several sources were found to change with time, indicating that the parts of the sources were separating as seen from the earth. The sources are thought to be very distant, so the simplest interpretation of the effect required very high apparent expansion velocities within the sources—in one source, nearly ten times the speed of light.

Since the possibility that matter is really moving with velocities in excess of the speed of light is not taken seriously by the experimenters, other alternatives have been explored. David DeYoung at NRAO has proposed an explanation in terms of the distribution of synchrotron radiation in a



Very Long Baseline interferometry, in which widely separated radio telescopes view the same object simultaneously to produce very high resolution, has used instruments in three continents in the past 2 years.

source expanding at nearly the speed of light. (Synchrontron radiation, first discovered in the accelerators bearing the same name, is produced when a charged particle moving at a speed very close to the speed of light passes through a magnetic field.) He found that sources with apparent expansion velocities in excess of the velocity of light can result from natural geometries and reasonable expansion rates due to the tricks played on the observer by the arrival time of light traveling from the source.

William Dent of the University of Massachusetts has proposed a motion-free model using data on source variability obtained from the Haystack Radio Telescope in Tyngsboro, Mass., supported by the Foundation's university research grants program. In his explanation, the central component of an aligned triple source gradually weakens and disappears. The mean spacing within the source, as measured by the interferometer, thus appears to increase without any mass motions taking place at all.

These and other models are presently being tested using further observation with new VLB systems recently completed at NRAO. If none of these "optical illusion" models can be confirmed, a possible alternative is that the sources are much closer than previously thought, so that the speed required for the source to move through the angle seen from the earth is less than the speed of light. In any event, it is clear that further study of this phenomenon will lead to a better understanding of the origin of radio galaxies and quasars.

Quasars

Quasars are one of modern astronomy's most challenging puzzles. They appear as starlike points, rather than as extended galaxies, even in the largest optical telescopes. Their radio wavelength emission is no different from that of more normal-appearing radio galaxies. However, their light is strongly displaced toward the longer wavelengths, producing a redshift. Establishing the cause of quasar redshifts is a controversial, fundamental problem facing astronomers.

The controversy arises because all of the major theories interpreting the redshifts lead to situations beyond our current comprehension of physics. Two proposed explanations hold that motion of the quasar away from us causes the shift via the so-called Doppler effect. In the first case, the motion is part of the overall, general expansion of the universe and the large shifts indicate that quasars are extremely distant and extraordinarily luminous. This is the cosmological interpretation. Since they appear as points, quasars must be relatively small compared to galaxies, even if they are far away. The problem in accepting this idea is that there is no known way to confine such strong energy sources in the small volumes apparent for quasars. The second theory holds that the high speeds result because the quasars were shot out of other nearby galaxies. Thus, the quasars themselves would not be excessively bright because they would be closer to us. On the other hand, there is no known way to eject anything at such high speed from a galaxy. A third suggestion is simply that the redshifts result from some unknown physical phenomenon, having little or nothing to do with motion.

For several years, it has been realized that a crucial observational test of the cosmological interpretation would be provided if a quasar could be found in a cluster of galaxies, and if it could be demonstrated that the redshifts of the "ordinary" galaxies in the cluster were the same as that of the quasar. Such a finding would, first, confirm the association of the quasar with the cluster of galaxies and, second, confirm the cosmological interpretation of the quasar redshift, since the cosmological interpretation of the redshift of "ordinary" galaxies is widely accepted. The quasar PKS 2251+11, which is surrounded by a small, compact cluster of galaxies, represents such a test case. L. B. Robinson and E. J. Wampler of the Lick Observatory recently measured redshifts for the two brightest ordinary galaxies in this cluster of galaxies and found them to be essentially equal to that of the quasar. One of the two galaxies is the faintest ordinary galaxy for which a redshift has ever been measured. The results of these difficult observations provide strong support for the cosmological interpretation of some quasars' redshifts.

These observations were made possible by the development of an image tube spectrum scanner by Dr. Wampler for use on the Lick Observatory 120-inch telescope. The development and application of state-of-the-art electro-optical detectors, sponsored jointly by NSF and NASA at the Lick Observatory, represents an important and exciting trend in contemporary astronomy. This trend emphasizes detector efficiency rather than telescope size, and is making intermediate-sized telescopes competitive in some respects with the present abilities of the world's largest telescopes.

MATHEMATICS

Finite Group Theory

One of the simplest and most useful of algebraic structures is the group. This concept has found applications in many branches of mathematics, as well as physics and chemistry. For example, the theory of finite groups has applications in crystallography, in the theory of inorganic complex ions, and in spectroscopy.

For a typical example, consider the ordinary plane, which we may think of as the surface of a very large table. A "move" consists of shifting the table and also pivoting it around its center. Two such moves may be combined by carrying out one after the other. If we first perform move M and then move N, the resulting combined move is called the composition MN of moves M and N. Composition of moves has interesting formal properties. There exists a move I, called the identity or neutral move, which consists of not displacing the table at all. For this move, I, we have $MI = M = IM$. For each move M there also is the inverse M^* of M, which undoes what M did, that is, such that $MM^* = I$. There is also the so-called associative rule for composition: $M(NP) = (MN)P$.

These formal properties of moves occur also in other situations and, by the process of abstraction from these various examples, algebraists have arrived at the notion of a group. A group is any set of elements with a composition law that has the formal properties described above. Thus, the moves described above form a group, but there are also many other groups which may occur under completely different circumstances. Perhaps the most familiar example of a group is the set of all integers where the operation to be performed is addition.

Groups are either *finite* or *infinite*, according to whether the set has a finite or infinite number of elements. A basic problem in the theory of finite groups is the determination of the structure of all finite groups. (For example, given a number n, how many groups with n elements are there?) In order to attack this problem, mathematicians have introduced the notion of a group which is, in some sense, indecomposable, the *simple group*. Simple groups are in a sense the building blocks for all groups. A classification of all finite simple groups would constitute decisive progress in the subject.

A major breakthrough in this area occurred in 1963, when W. Feit and J. Thompson showed that essentially every simple group has an even number of elements. There are now indications that Dr. Thompson has taken another great step: He seems to have succeeded in classifying all simple groups such that the number of elements is not divisible by three.

There are some finite simple groups that may be called classical. By the early 1960's, these had been thoroughly sorted out. Thus, the remaining task is to find all the nonclassical finite simple groups (called *sporadic* groups). As long ago as 1861, E. Mathieu discovered five such groups.

For over 100 years it was thought that these were the only ones. However, in 1965, Z. Janko startled the mathematical community with the discovery of a new sporadic group and, shortly thereafter, contributed to the discovery of an additional two. At present, there are 20 known sporadic groups. One of the large groups, Co$_1$, is, incidentally, quite remarkable in two ways. One, it arose from a study by J. Leech of close packing of spheres in 24 dimensions (a problem related to the theory of error-correcting codes). Two, this group surprisingly contains copies of many others on the list.

It is clear that finite simple groups exist in greater abundance than had recently been suspected. It remains to be seen whether the list of sporadic groups can be shown to have only finitely many isolated members or, if there are infinitely many new simple groups to be found, whether they will form a natural family with a sensible structure. Many mathematicians are working on these and related questions in this active area of research, some of which is being carried out by a skillful combination of handwork and large, high-speed electronic computers.

BIOLOGICAL AND MEDICAL SCIENCES

Research programs continue to study complex biological systems so as to increase our understanding of the structures and functions of living things and their relationships and interactions with other organisms and their environment. Such research is relevant not only to our basic livelihood but also to major societal problems such as environmental pollution, population levels, food production, physical and mental health, and effective use of resources.

Although a significant portion of the increased funds for biological research in fiscal year 1972 replaced support which had previously been provided by other Federal agencies, support was also increased in several areas of special need or opportunity.

One such area is research on learning and memory. A new program was established for neurobiology, which will work closely with the Psychobiol-

THE TWENTY KNOWN SPORADIC GROUPS

GROUP	DISCOVERED	NUMBER OF ELEMENTS		
M$_{11}$	1860—MATHIEU	$2^4 \cdot 3^2 \cdot 5 \cdot 11$	=	7,920
M$_{12}$	1860 "	$2^6 \cdot 3^3 \cdot 5 \cdot 11$	=	95,040
M$_{22}$	1861 "	$2^7 \cdot 3^2 \cdot 5 \cdot 7 \cdot 11$	=	443,520
M$_{23}$	1861 "	$2^7 \cdot 3^2 \cdot 5 \cdot 7 \cdot 11 \cdot 23$	=	10,200,960
M$_{24}$	1861 "	$2^{10} \cdot 3^3 \cdot 5 \cdot 7 \cdot 11 \cdot 23$	=	244,823,040
Ja	1965—JANKO	$2^3 \cdot 3 \cdot 5 \cdot 7 \cdot 11 \cdot 19$	=	175,560
HaJ	1967—HALL, JANKO	$2^7 \cdot 3^3 \cdot 5^2 \cdot 7$	=	604,800
HJM	1968—HIGMAN, McKAY, JANKO	$2^7 \cdot 3^5 \cdot 5 \cdot 17 \cdot 19$	=	50,232,960
HHM	1967—HELD, HIGMAN, McKAY	$2^{10} \cdot 3^3 \cdot 5^2 \cdot 7^3 \cdot 17$	=	4,030,387,200
HiS	1967—HIGMAN, SIMS	$2^9 \cdot 3^2 \cdot 5^3 \cdot 7 \cdot 11$	=	44,352,000
McL	1968—McLAUGHLIN	$2^7 \cdot 3^6 \cdot 5^3 \cdot 7 \cdot 11$	=	898,128,000
Suz	1967—SUZUKI	$2^{13} \cdot 3^7 \cdot 5^2 \cdot 7 \cdot 11 \cdot 13$	=	448,345,497,600
Co$_1$	1968—CONW[illegible]	$2^{21} \cdot 3^9 \cdot 5^4 \cdot 7^2 \cdot 11 \cdot 13 \cdot 23$	=	4,157,771,806,543,360,000
Co$_2$	1968 "	$2^{18} \cdot 3^6 \cdot 5^3 \cdot 7 \cdot 11 \cdot 23$	=	42,305,421,312,000
Co$_3$	1968 "	$2^{10} \cdot 3^7 \cdot 5^3 \cdot 7 \cdot 11 \cdot 23$	=	495,766,656,000
Fi$_{22}$	1969—FISCHER	$2^{17} \cdot 3^9 \cdot 5^2 \cdot 7 \cdot 11 \cdot 13$	=	64,561,751,654,400
Fi$_{23}$	1969 "	$2^{18} \cdot 3^{13} \cdot 5^2 \cdot 7 \cdot 11 \cdot 13 \cdot 17 \cdot 23$	=	4,089,470,473,293,004,800
Fi$_{24}$	1969 "	$2^{21} \cdot 3^{16} \cdot 5^2 \cdot 7^3 \cdot 11 \cdot 13 \cdot 17 \cdot 23 \cdot 29$	=	1,252,205,709,190,661,721,292,800
LyS	1971—LYONS, SIMS	$2^8 \cdot 3^7 \cdot 5^6 \cdot 7 \cdot 11 \cdot 31 \cdot 37 \cdot 67$	=	51,765,179,004,000,000
RCW	1972—RUDVALIS, CONWAY, WALES	$2^{14} \cdot 3^3 \cdot 5^3 \cdot 7 \cdot 13 \cdot 29$	=	145,926,144,000

ogy Program. Increased support was provided for research projects ranging from those dealing with the molecular basis of sensory and neural processes to those which examine integrated cognitive processes. Steps have also been taken to support coherent approaches to particular aspects of learning. Scientists at the University of Colorado are working on verbal, conceptual, and semantic factors in complex human learning, memory, thinking, and comprehension. At the University of Minnesota, the Center for Research on Human Learning has a broad program which combines basic research on learning with an applied approach to educational problems. For the first time, the Foundation has also provided major support for a project to examine genetic factors in human learning. This research will be conducted at the University of Hawaii with the collaboration of scientists from the University of Colorado.

A new program for Human Cell Biology was established to strengthen the application of the knowledge and methods of molecular biology and genetics to research on human cells in tissue culture. The problem of making cultured cells available in large quantities is critical to progress in this field, and the need for production centers has received much attention. Efforts in the coming year will be directed to stimulating collaborative efforts to make more economical and effective use of common production facilities.

The Foundation has also substantially increased its support of the research collections of museums and herbaria during fiscal year 1972. Support for biological research resources has been provided in many ways. Only in the case of genetic stock centers, however, supported through the Genetic Biology Program, has a consistent effort been made to ensure the existence of resources considered essential for research in an area of biology. Private, State, and local funds have provided for the housing and care of the collections of plants and animals essential for research in systematic biology. These sources have become increasingly inadequate as research activities have grown, and will become increasingly so as environmental research expands. Although the need for building, renovation, and care of collections far exceeds the present financial capabilities of the Foundation, a program of curatorial support was initiated with 13 grants in fiscal year 1972 in order to make particularly significant collections more available for research, and to maintain records of biota which are changing rapidly as the result of man's environmental interventions. The Foundation has entered this venture in a limited way, anticipating that the maintenance of collections will remain a shared responsibility of local, State, and Federal Government and private philanthropy.

Substantially increased support has also been provided for research on the biological regulation of pest populations. Much of this research is distributed among the interests of several BMS programs, but a major plan for integrated research on pest management was also developed within the International Biological Program. This project, titled Principles, Strategies and Tactics of Pest Population Regulation in Major Crop Ecosystems, is being jointly supported by the Foundation, the Department of Agriculture, and the Environmental Protection Agency. Research will be conducted on six crop and forest systems, and will involve scientists from 19 universities, as well as those from State and Federal agencies, and private sectors. In the view of those who have planned this research, the program conforms in all its essentials to a major recommendation of the Third Annual Report of the National Science Board *Environmental Science—Challenge for the Seventies* (1971), which urged greater interdepartmental and interdisciplinary research and a more effective use of the talents of industry, government, and universities in new types of research organizations.

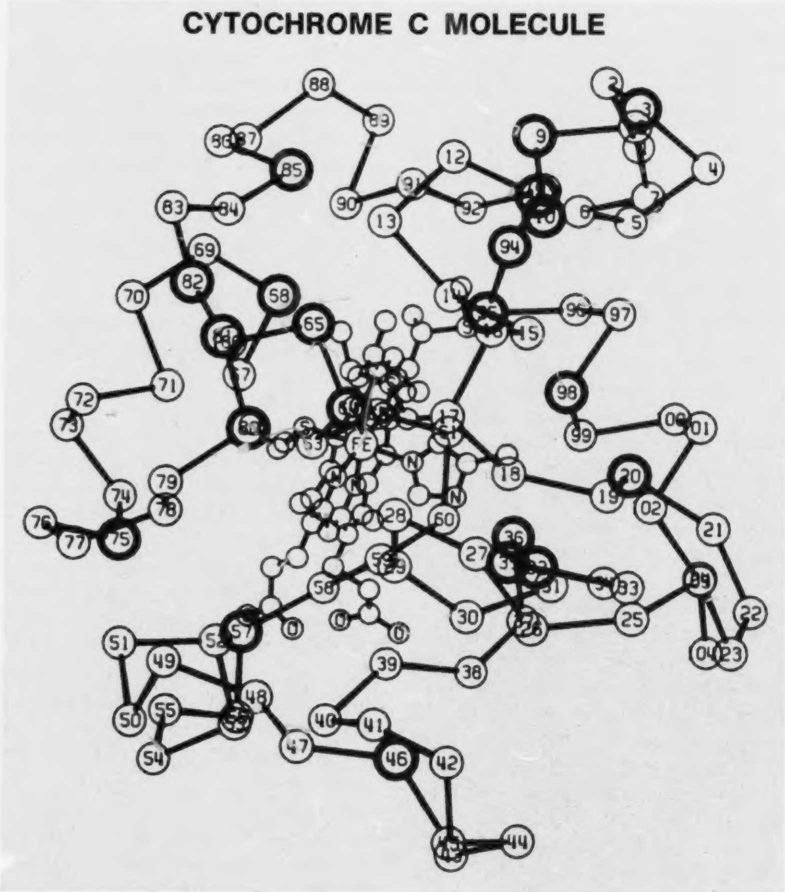
Evolution of a Molecule

At first glance, a clam, a worm, and a horse would seem to have little or nothing in common. Actually, their chemical machineries have important similarities at the molecular level, particularly in the way they obtain energy by combining food molecules with oxygen by use of a protein, cytochrome c.

A variant of cytochrome c exists in each organism that uses oxygen for respiration. In higher forms of plants and animals, including man, approximately 104 amino acid units are linked together and folded into a specific three-dimensional structure. In primitive organisms such as yeasts and molds, the three-dimensional structure of cytochrome c is essentially the same as for higher organisms, but the numbers and sequence of amino acids are different. Fortunately, the molecule is comparatively small and readily purified so that detailed diagrams have been made of the structure and composition of cytochrome c in more than 40 different organisms.

A molecule that is ubiquitous, vital to life, and shows variations between advanced and primitive organisms has obvious advantages for evolutionary studies. These advantages are enhanced by the fact that the degree of difference between the cytochrome c molecules in different species correlates with the degree of difference in their evolutionary development.

Considering the wide distribution of the cytochrome c molecules in all living organisms, we might ask to what extent has it remained unchanged during the course of evolution? Or what features of the structure have remained unchanged, and are they important in preserving the functional properties of the molecule? In comparing locations of the 104 amino acid units on cytochrome c from various organisms, researchers have found 35 identical amino acids in identical positions. At 19 other positions the amino acids differ only in a relatively minor way. One can



Within almost every living person, animal, and plant is a variant of the protein molecule cytochrome c consisting of 104 amino acid units of various types and in various locations according to the species. Scientists have found that the degree of difference between the molecules in different species correlates with the degree of difference in their evolutionary development. This particular diagram is of horse cytochrome c.

infer that amino acids at these invariant or relatively invariant positions play a key role in the chemical work of the molecule. However, a direct test can only be provided by examining the three-dimensional structure of cytochrome c, with particular reference to the clustering of amino acid side chains around a group of carbon, nitrogen, and iron atoms called the heme group.

Richard E. Dickerson and associates at the California Institute of Technology have been working on the X-ray diffraction analysis of the cytochrome c structure since about 1963, with grants from the National Science Foundation and the National Institutes of Health. Through high resolution diagrams of cytochrome c, they showed that the constant amino acids which always occupy the same position in the chain are those that allow the molecular chain to fold around the heme group and bring certain amino acids into the environment of the heme. They also show regions of the exterior surface with amino acids of limited variation. These regions are probably involved in reactions with the cytochrome oxidase and cytochrome reductase molecules which are required for oxygen utilization.

It now appears that there was some primitive ancestor of both plants and animals which derived the major portion of its energy from oxygen and which had cytochrome c as a part of its metabolism. The gene for this cytochrome c would periodically undergo mutation due to some change in the DNA, and a different amino acid would be inserted at some point in the molecular chain. If an amino acid were introduced at a position which produced a nonfunctional cytochrome c, the mutant organism would, in effect, suffocate because it would be unable to use oxygen and, therefore, would disappear. If, however, the mutation produced an altered amino acid in a less critical position, the new cytochrome c might function about as well as the normal form. Such a mutant would live, produce progeny, and become fixed in the population. Subsequent mutations might occur [illegible] the gene for the original cytochrome c, or in the new form. On the basis of this hypothesis, one should be able to decide whether a more highly modified form of cytochrome c came from the original parent or from the first mutant form. Development of diverging branches in the evolution of molecules can be determined in this way, and "phylogenetic trees" constructed. It is possible to conclude that it has taken about 20 million years to produce a change of 1 percent in the amino acid sequence of cytochromes and that plants and animals took their separate paths in evolution some 1.2 billion years ago.

An evolutionarily stable molecule like cytochrome c, serving a critical role in an essential process such as respiration, however, cannot be expected to give an insight into broader aspects of molecular evolution. Other protein molecules, which have less stringent functional requirements, have evolved more rapidly, and differ-

DIFFERENCES IN AMINO ACID SEQUENCES IN THE CYTOCHROMES C FROM SELECTED SPECIES OF ANIMALS AND PLANTS

	Human	Monkey	Horse	Dog	Kangaroo	Chicken	Rattlesnake	Turtle	Fish	Moth	Yeast
Human	0										
Monkey	1	0									
Horse	12	11	0								
Dog	11	10	6	0							
Kangaroo	10	11	7	7	0						
Chicken	13	12	11	10	12	0					
Rattlesnake	14	15	22	21	21	19	0				
Turtle	15	14	11	9	11	8	22	0			
Fish	21	21	19	18	18	17	26	18	0		
Moth	31	30	29	25	28	28	31	28	32	0	
Yeast	45	45	46	45	46	46	47	49	47	47	0

By comparing the differences of types and positions of amino acid units on the cytochrome c molecules of different species, researchers have found the number of these differences between species corresponds to evolutionary differences. For example, there is only a single difference between man and monkey, 12 between man and horse, 14-15 between man and reptile, 21 between man and fish, and 45 between man and yeast. Other differences exist between species. For example, there are 11 differences between a chicken and a horse, 26 between a fish and a rattlesnake, and 47 between yeast and a moth.

ences in the structure of proteins can be found between individuals of the same species which are otherwise not notably different. These differences between and within populations are the material upon which natural selection operates. However, the relations are so complex and the molecular basis of structure and function so poorly understood that many other approaches to the study of molecular evolution are needed.

Nitrogen Fixation

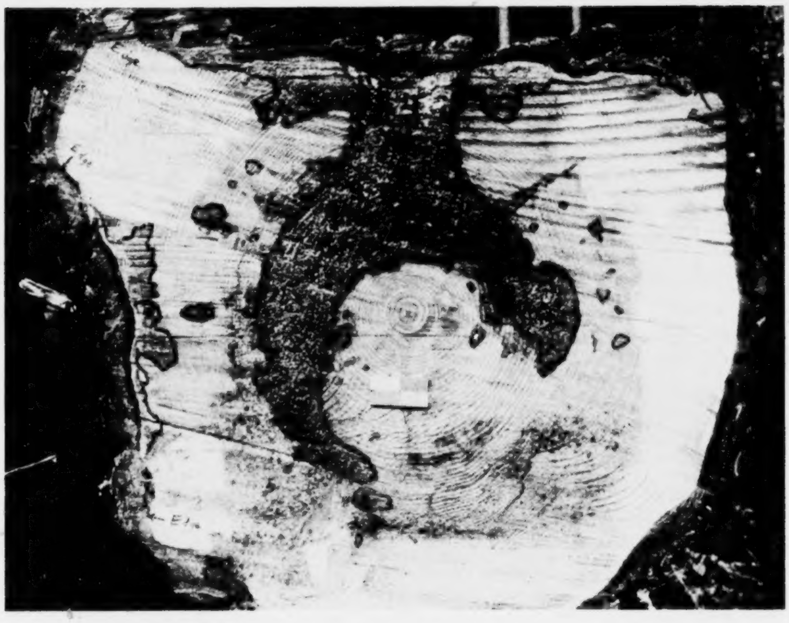
The ability of certain plants to take their required nitrogen from the atmosphere instead of from chemical fertilizers is vital to the present and future nutritional and ecological needs of the world's growing population. To meet these needs, enormous increases must be made in production of protein-rich crops such as wheat and grains and other food crops such as corn and rice. The major factor in increasing these crops is the presence of nitrogen, a substance essential for their life processes.

At present, nitrogen is supplied to plants in two ways—through the nitrogen fixation process by which certain leguminous plants as peas, beans, and soybeans "fix" or take into their systems nitrogen from the atmosphere by means of symbiotic soil microorganisms. The other method is by the application of inorganic chemical fertilizers. It is anticipated that increases in crop output through increased artificial fertilizer use will reach a plateau in about 5 years for several reasons. Costs are increasing to the point of diminishing returns and, more significantly, the availability of nitrogen in this form does not correspond to the varying needs of the growing plants, with the result that only about half of the nitrogen applied as fertilizer is used by the plant. The excess nitrogen is dissipated as runoff and is creating one of our major and increasingly costly pollution problems. While chemical fertilizers provide about 7 million tons of nitrogen a year, worth $0.42 billion, the nitrogen fixation process provides the major source of nitrogen: a minimum of 12 million tons of nitrogen a year, worth about $1.3 billion.

Fundamental studies of biological nitrogen fixation supported by NSF include biochemical, physiological, and genetic aspects, all bearing on the entire area of nitrogen fixation research. Two projects in particular take different attacks, one having immediate practical application of basic scientific discoveries and the other having future implications for solving many nutritional problems.

A research group at Oregon State University has provided new information about the fungus-induced decay in the heartwood of white fir trees, estimated to be a loss of over 1.2 billion board-feet each year. Up to now, efforts to cope with the problem were not very effective. Since wood does not contain much nitrogen, it was not clear how the nitrogen-requiring fungus thrives in trees. By joint experimental efforts, an atmospheric nitrogen-fixing bacterium—probably a new species—was found living in symbiotic relation with the fungus, providing the wood-destroying fungus with necessary nitrogen. Now the problem of controlling this decay can be based on a specific approach rather than on previous expensive and inadequate approaches.

Another nitrogen fixation research is somewhat more complex, and its full implication has yet to be explored. In studying the development



Nitrogen-fixing bacteria have been discovered supplying essential nitrogen to fungi that cause decay in living fir trees of the Northwest. This picture of a cross section of white pine shows the cankers and decay caused by the thriving fungus within the tree's heartwood. (Photo by Paul Aho, U.S. Forest Service)

of hybrids between nitrogen-fixing plants and nitrogen-consuming plants, a research team performed an experiment of moving a piece of nitrogen-fixing genetic material from *Klebsiella* bacteria into *E. coli,* an intestinal organism, which then itself began to fix nitrogen. The implication of such an experiment is important, for it demonstrated the future feasibility of inserting critical genetic material into economically important plants such as corn, wheat, rice, and other food and fiber crops to enable them to fix atmospheric nitrogen on their own, hence reducing the need for chemical fertilizers.

Information Systems of Cells

A biological problem of major significance is intracellular ecology. The fact is that the information bits inside a cell are precisely ordered. But how did the order originate, how is it perpetuated as cells are replicated, and what is its meaning? Classical experiments indicate that specific signals, originating in the cytoplasm, eventually determine the course of development of a cell. The targets of such signals are the genes. Two current investigations start with existence of specific signals and aim at discovering the cytoplasmic organelles from which these originate, the nature of the signals, and the manner in which the genes receive and accurately interpret the information provided to them.

Polar granules, found in the eggs of insects and of certain vertebrates, are organelles which send signals instructing the cells in which they reside to develop into germ cells. If the granules are removed or damaged—by ultraviolet radiation for example—then an adult which lacks germ cells is formed. If these granules are reinjected into a previously operated organism, the germ cells will be formed. What researchers are trying to find is the mechanism, at the molecular level, by which the polar granules signal the genes in the cells in which they reside and thus determine their fate.

The first step towards this goal is clear. Polar granules need to be isolated and purified by the "bucketfull" and then analyzed chemically. Anthony P. Mahowald at Indiana University has had continuing support from the National Science Foundation to tackle this fundamental problem. His favorite material is *Drosophila* because of the fact that exceedingly large numbers of individuals can be raised for analysis, and also there is a wealth of background genetic and developmental work on this organism. With zonal centrifugation through shallow sucrose gradients, pelleted material has been obtained, about 10 percent of which is polar granules, representing a thousandfold enrichment. Progress in this research has been slow, yet it has been gratifyingly steady.

The same broad problem of signalling, from cytoplasmic organelles to the nucleus, is under investigation by Noel De Terra at the Institute of Cancer Research in Philadelphia. Her material is the ciliate, *Stentor.* The special advantages of this cell are its large size and its capacity for wound healing, permitting both detailed intracellular localization by autoradiography and microsurgery. The basic observation is that changes in the nucleus which prepare the cell for division by duplicating the DNA content are precisely geared to changes in the cell cortex, particularly the oral region, which is also readying the cell for division. When two cells in *different stages* of oral differentiation are grafted together, they very soon become synchronized with respect to their nuclear events. This result and others show that the nuclear cycle is initiated and controlled by a "backbone" mechanism located in the organelles comprising the cell surface. Signals are transmitted from the cortex to the nucleus either by extremely short-range diffusion or by means of structural connections between the cell surface and the nucleus. Attempts to distinguish these two hypotheses are under way.

ENVIRONMENTAL SCIENCES

Environmental phenomena of the solid earth, the oceans, and the atmosphere surrounding the earth and including the energy-producing sun have substantial impact on man and other living creatures. Understanding natural forces, learning what causes them and how they affect the livelihood of man, and perhaps trying to forecast or even control them, are some of the objectives of environmental research.

Research studies concerning atmospheric, earth, and oceanographic science may relate to local geographic areas or may be of such broad scope that extensive international coordination of planning, management, funding, and logistic support are essential. In some cases, large-scale field operations are undertaken requiring the use of ships, aircraft, satellites, and other facilities. This year, U.S. scientists were increasingly involved with scientists from many nations in planning international programs and carrying out research projects of mutual interest. Studies of environmental phenomena are primarily based at universities, oceanographic institutes, and at the National Center for Atmospheric Research at Boulder, Colo.

Studies of weather and climate on medium and global scales continued to receive major attention in the *atmospheric sciences*, as did investigations in atmospheric chemistry, inadvertent weather modification, atmospheric electricity, and the physics of water transformations within clouds. Many aeronomy research projects of the upper atmosphere dealt with interactions between ionospheric constituents and energetic particles and radiation. The solar atmosphere and solar wind, and the reaction of the latter with the earth's magnetic field and ionosphere, were subjects of numerous research projects. To study the total eclipse of the sun in June of 1973, research projects are being planned for Africa where the greatest part of the eclipse will take place.

University research aimed at understanding the dynamics of worldwide weather and its prediction is supported through the Global Atmospheric Research Program (GARP). One immediate objective of this international program is to determine the types, frequencies, and density spacing of observations needed to create models of atmospheric behavior. A major international experiment, known as the GARP Atlantic Tropical Experiment (GATE), is planned for the summer of 1974 in the eastern part of the equatorial Atlantic Ocean, as well as in a belt across the ocean and including parts of Africa and South America. This experiment is particularly important because the tropical oceans receive the major part of the solar energy that ultimately controls worldwide weather systems.

In the *earth sciences*, concepts of seafloor spreading and plate tectonics continue to be tested and studies made on their role in mountain building, seismic activity, volcanism, sedimentation, and the postpaleozoic history of the continental plates. Research projects now exploring continental drift and geologic history include studies on stratigraphy, paleontology, geophysics, and the geochemistry of igneous rocks. Also, since the damaging San Fernando earthquake of February 1971, investigators have become more interested in techniques that might lead to increased understanding and possible prediction of earthquakes.

Major support for *oceanographic research* continued to be in physical and chemical oceanography, geology and geophysics of the ocean basins, and biology and ecology of marine organisms. Of particular interest in geological research were the core samples produced by the Ocean Sediment Coring Program.

Studies of Lake Ontario by university scientists were initiated under the International Field Year for the Great Lakes. This is a cooperative program between the United States and Canada, with several agencies of both countries involved. The ultimate aim of the program is to improve the scientific basis for management of Great Lakes resources.

ATMOSPHERIC SCIENCES

The NCAR Global Circulation Model

Numerical simulation of the global atmosphere provides a framework within which the many physical processes that function as components of complex atmospheric systems can be assembled and their relative importance in the large-scale behavior of the atmosphere can be tested. At the National Center for Atmospheric Research (NCAR), a major effort in numerical simulation is centered around the global circulation model (GCM). During fiscal year 1972, development continued on the standard version of the GCM which has a network for the entire globe with a vertical grid spacing of six levels at 3-kilometer intervals plus the surface level, and a horizontal grid spacing of either 5° or 2.5° in latitude and longitude. This model allows for variations in cloudiness, soil moisture, and snow cover. Recent GCM studies of the effects of mountains have indicated that mountain ranges are of little importance in simulating large features of the atmosphere, although they can be quite important on the regional scale.

The NCAR global circulation model has a unique modular design that permits its use in a variety of experiments by substituting different components for those used in the standard GCM. Thus, it can be made available for a number of joint studies with other scientists at NCAR, universities, and other institutions. Some recent joint projects have involved:

- Investigations of cumulus convection, by scientists at Florida State University, that should lead to improved studies of latent heat release in the tropics in global-scale numerical simulation.
- A complex photochemical treatment for the production of ozone, to be tested in the GCM's stratospheric version, being developed by scientists from the University of Colorado and from the Swiss Federal Institute of Technology.
- A study of possible effects of thermal pollution on global climate, undertaken at the request of Oak Ridge National Laboratory.

Encouraged by their success in developing a tropospheric model, NCAR scientists began designing a stratospheric global circulation model. Because the troposphere is a major source of energy for the stratospheric circulation, it was necessary to have a good tropospheric model before attempting to model the stratosphere. It appears that an intricate interaction between the troposphere and the stratosphere may play an important role in climatic fluctuations.

Numerical experiments related to the design of observing systems for the Global Atmospheric Research Program (GARP) continued at NCAR (see pages 38 to 39).

Identification of Solar M-Regions

The interdisciplinary field of solar-terrestrial physics deals with interrelationships among solar, interplanetary, magnetospheric, ionospheric, and atmospheric phenomena. In recent years, measurements made by spacecraft have provided direct knowledge of the magnetosphere and interplanetary space that offers a new and different picture of the relationships between solar activity, the solar wind, and geomagnetic activity.

The synthesis of this new material with recent theoretical advances from NCAR's High Altitude Observatory has thrown new light on the identity of so-called solar "M-regions" or sources emitting solar particles. For many years, it has been recognized that phenomena in the terrestrial upper atmosphere, notably changes in the magnetic field, tend to be periodic, repeating with the solar rotation period of about 27 days. These disturbances were widely attributed to beams of particles emitted from some long-lived solar sources. However, the location and nature of the solar "M-regions" producing these beams were not clear. The principal difficulties in tracing the solar-particle beams back to their origin on the sun lay in the possible deflection of the particles by coronal magnetic fields and in the spiral paths traced by the beams in interplanetary space. The latter effect, produced by solar rotation, could be understood only when direct measurements of the particle speeds became available.

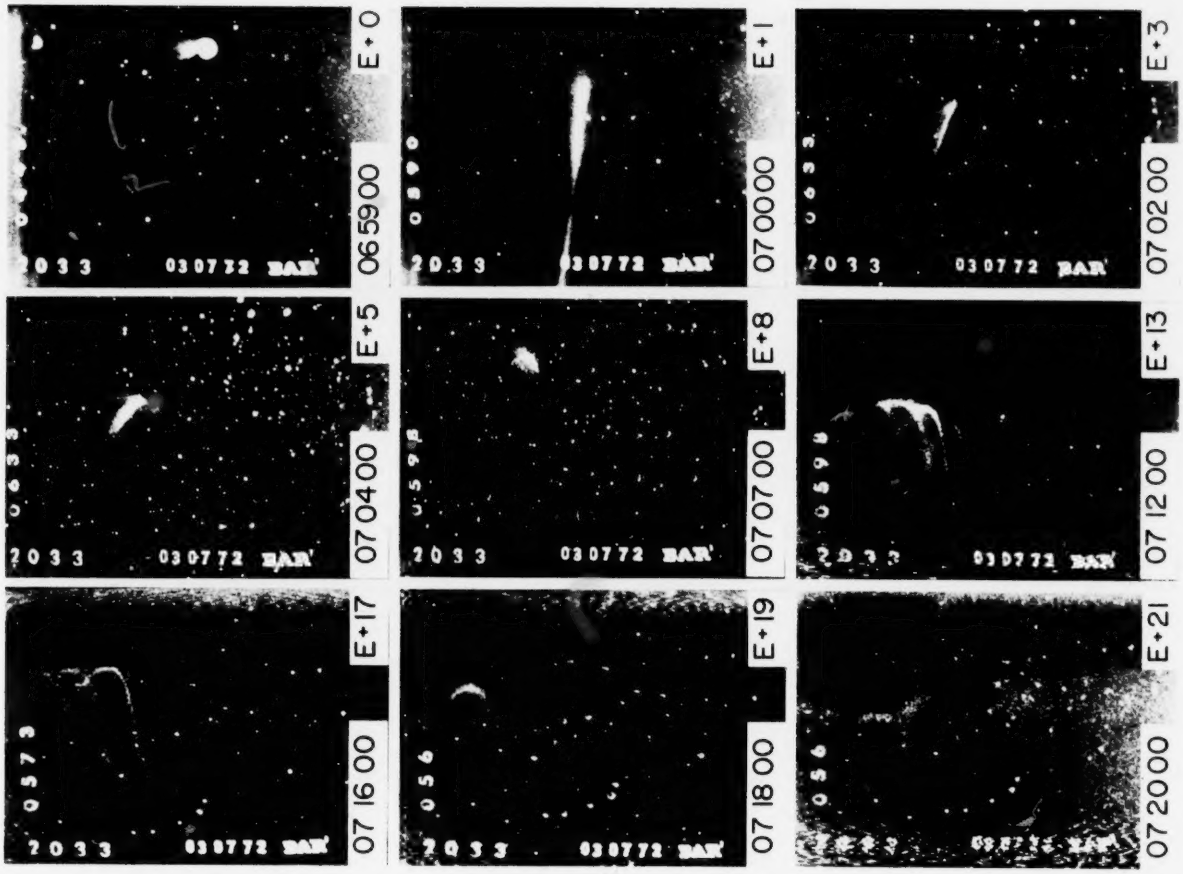
Three lines of evidence developed by NCAR scientists point toward a resolution of this problem. A detailed theoretical model treating the formation of the solar wind in the presence of a coronal magnetic field indicates that the magnetic lines of force are open above magnetically simple "quiet" regions on the sun, allowing an outward flow of gas. But the lines of force are closed above magnetically complex active regions, preventing any outward flow. The spiral beam configurations deduced from observed particle speeds and the magnetic characteristics of the beams also imply an origin in the open magnetic field lines. Finally, a strong correlation of open magnetic field configurations with geomagnetic activity has been found. These three studies argue strongly that "M-regions" are related to the magnetic channeling of the outward-flowing coronal plasma, and are not associated with solar activity.

Magnetospheric Electric Fields

The magnetosphere—that portion of space influenced by the earth's magnetic field—contains a wide variety of particles with energies ranging from thermal energy to tens of millions of electron volts. These particles are charged (ionized) and form a state of matter called plasma. Because the plasma in the magnetosphere is fairly accessible, undergoes a wide range of natural disturbance levels, and is not dominated by energy losses for short lengths of time, it is perhaps the best magnetized plasma in which to study little known or unknown processes in electric field generation and particle acceleration.

Particles in the magnetosphere are controlled by magnetic and electric fields in addition to the gravitational forces and gas pressure laws that are the dominating effects in the lower atmosphere. During the past year, a number of electric field measurements have been made on the magnetosphere, with the majority of the data applying to its low altitude boundary, the ionosphere. Despite these additional measurements, existing models of the magnetosphere have not been able to provide an accurate extrapolation of electric fields measured near the pole to those fields at great distances several thousand kilometers from earth. Yet, by assuming that magnetic field lines are electrical equipotentials, researchers at the University of California, Berkeley, and the University of Alaska have calculated electric fields in space above the equator. The resulting estimates are reasonably compatible with values presently known from spacecraft experiments.

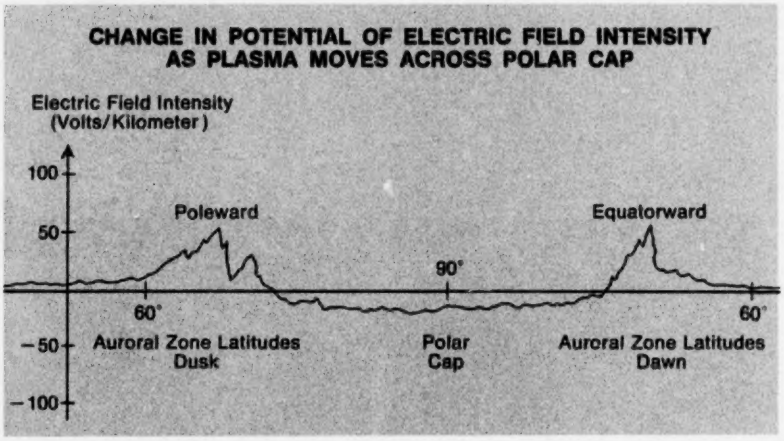
One technique for deducing magnetospheric electric fields is the observation of specific motions of very low frequency whistler waves—radio signals which arch out into space along the lines of the earth's magnetic field from pole to pole some 60,000 to 80,000 kilometers toward the sun. Other techniques include the use of



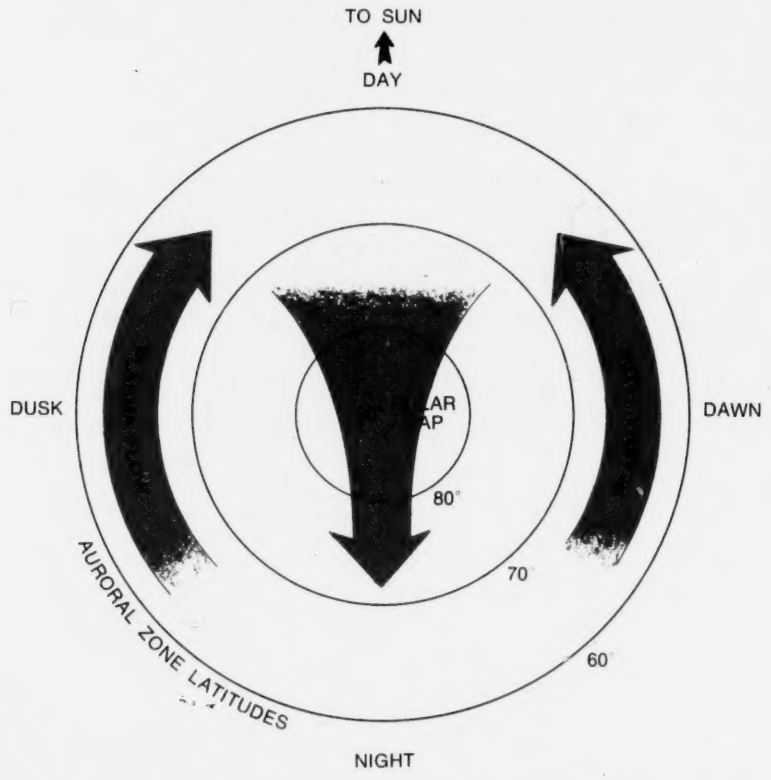
Released from rockets, barium vapor moves at high speed along the earth's magnetic field, thus making the field line "visible" for a great distance, as shown in this series of photographs tracing the barium. Plasma instabilities cause the streak to break into multiple striations, as clearly seen at E + 13 minutes. (Photos by Geophysical Institute, University of Alaska) electric field probes on balloons floating underneath the ionosphere, the tracing of motions of ionized barium clouds released into the ionosphere from rockets, and measurements of the velocity of the ambient ionosphere plasma by backscattered radars.

Observations indicate that magnetospheric electric fields can be correlated with large-scale convection patterns of the global plasma motion and associated fields at ionospheric levels.

At high latitudes, including the auroral zones of around 60-65° latitude and the polar caps, the basic pattern of plasma motion has been traced. The plasma moves in paths away from the sun across the polar cap and returns toward the sun in the lower latitudes of the auroral zones—in regions of twilight of both dawn and dusk. The electric field is intimately associated with this motion and from measurements of this field, researchers have found that the potential of the magnetospheric field voltage drops some 20 to 100 kilovolts across the polar cap. This drop is roughly equal and opposite to the sum of the dawn and dusk potential changes in kilovolts in the adjacent auroral zones.


CHANGE IN POTENTIAL OF ELECTRIC FIELD INTENSITY AS PLASMA MOVES ACROSS POLAR CAP

The motion of the magnetospheric plasma at high latitudes is associated with an electric field. The basic distribution of this electric field leads to a change in potential of tens of kilovolts across the polar cap.


FLOW PATTERNS OF MAGNETOSPHERIC PLASMA AT HIGH LATITUDES
(Diagram looks down on earth from above Polar Cap)

At the earth's high latitudes, the magnetospheric plasma moves in paths away from the sun across the polar cap and returns toward the sun in the auroral zone latitudes (around 60° to 70° geomagnetic), in the twilight regions of dawn and dusk.

Many types of detailed variations in the distribution of magnetospheric electric fields which occur in association with perturbations called magnetospheric substorms remain to be satisfactorily explained, and the important question as to how solar wind energy and momentum are drawn upon to drive magnetospheric convection awaits a definitive treatment.

EARTH SCIENCES

Thermal Convection in Geologic Systems

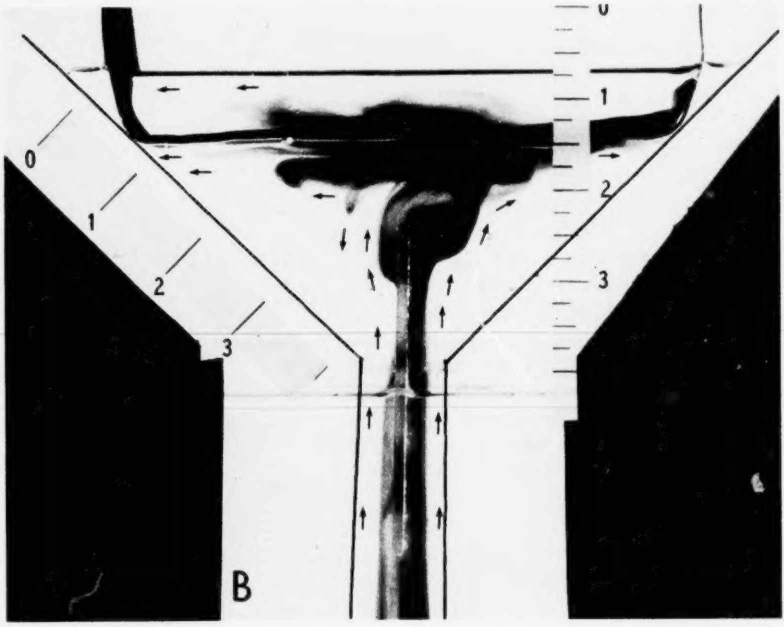
Thermal convection within the earth is the process that is probably responsible for the transfer of heat and plastic material from deep within the mantle toward the solid crust of the earth. It is believed to be an important part of the driving mechanism for seafloor spreading and the movement of huge slabs of the earth's crust, and it may be especially significant in the movement of molten materials that form a variety of igneous rocks. Because thermal convection occurs deep within the earth, it cannot be observed directly, and it must be studied through controlled laboratory experimentation to determine the nature of convective cells, their patterns, and movements of materials under different thermal gradients and different boundary conditions.

Such a laboratory study is being carried out by Somdev Bhattacharji, Brooklyn College of the City University of New York, who has focused attention on the origin of certain funnel-shaped bodies and connecting "pipe" structures. Such geological "pipes" may be conduits through which convective currents transfer hot molten materials from deep to shallow areas where the melt crystallizes. Studies of the pipes can provide fundamental data on the chemical and physical history of the upper mantle, as well as the evolution of structures during movement and solidification of molten materials. It is worth noting also that igneous rocks associated with these geological pipes are sources of many economically important minerals.

Dr. Bhattacharji has given special attention to the physical and structural properties of laboratory models. Liquids of suitable physical and thermal properties and solids of various densities, sizes, and shapes, simulating properties of various plastic molten rock materials and natural minerals, were placed in a specially designed apparatus that allowed heating of the mixtures to produce convective flow. Convective cell patterns were recorded photographically. Mixtures of coconut oil/water and oil/silicone fluids of varying viscosities were used to simulate immiscible and slightly miscible molten fluid rock, and plastic fragments were used to simulate certain mineral species. Thermistor probes measured temperatures at numerous points in both fluids. Heat was applied to the lower fluid and the patterns of heat transfer and movement of material were observed.

Flow patterns developed in the experiment showed a number of characteristics of geologic significance. For example, certain flow patterns were found to be antisymmetrical (wall-to-wall) rather than symmetrical (center-to-wall), reflecting a distribution of material considered to be of particular relevance in the development of geologic structures as well as in the understanding of chemical and petrological variations in volcanic vents and pipes. The study also indicated that convection, under certain flow patterns combined with differential gravity settling of "mineral grains," produces layering, a prominent feature of many rocks we see exposed today. Also, as predicted, convective turbulence facilitates prolonged suspension of mineral grains. This, together with differential gravity settling of crystals of various sizes, shapes, and densities, leads to a sorting action. Coupled with convective pulsation, rhythmic layering is produced in experimentally developed funnel-shaped bodies. Rhythmic layering is common in certain natural igneous rocks, such as the chromite-bearing rocks of South Africa. Teardroplike structures develop when a dominant vertical thermal gradient is modified by fast chilling from above.

The strong similarity of experimentally developed structures to those found in some igneous rock bodies is notable and demonstrates the applicability of laboratory modeling as a significant approach to the understanding of many geological processes.



In a laboratory study of thermal convection patterns, crystals in fluids, simulating natural minerals and molten rock, rise from a heated base to the chilled roof area, then drop in teardrop-like density currents and flow patterns.

OCEANOGRAPHY

The Sea in Motion

Central to physical and chemical oceanographic research is understanding of the physical processes that keep the sea in motion. Some important driving forces are the tides, the wind, and variations in atmospheric pressure and in water densities. Notable progress in understanding the response of the ocean to these forces was made last year by Carl Wunsch of the Massachusetts Institute of Technology. He studied 8 years of sea level records that were taken at the Bermuda Biological Station, in an attempt to resolve the various sea level oscillations into components ranging from one cycle per 8 years to one-half cycle per hour.

He concludes that the North Atlantic Ocean has a natural vibration period of 14.8 hours. He also found that the dissipation rate for the tides is so strong that if the forces affecting tides were to cease, the amplitude of the tides would decrease by one-third in 10 hours. This latter conclusion establishes the need for greater understanding of the dynamics of the ocean near the continental margins, for it is here that the energy of the tides is either being dissipated or converted to other motions.

Dr. Wunsch further concludes that, excluding the lunar and solar tides, the sea level is dominated by atmospheric pressure variations for periods shorter than a year. At longer periods, the forcing due to wind stress was dominant. The effect of atmospheric temperature was found to be negligible.

In addition, Dr. Wunsch used data taken from the ship *Panulirus*, sampling at a regular position near Bermuda, to interpret the consequences of internal motions on the sea level, with the conclusion that internal waves have a negligible effect on sea level.

This study has several major links with other programs. First, it demonstrates that it is possible to independently measure high frequency internal motions within the sea without having many influencing effects from variations in sea levels. Second, storm surges due to barometric pressure and winds often cause abnormally high tides along coastal areas of the United States. Adequate prediction of storm tides requires knowledge of the deep sea tides and continental shelf modifications to these tides. This work has established several premises that all future studies on tides must contain. Particularly, adequate knowledge of the resonance period and dissipation rate is required in all tidal computer models. The high dissipation rate found for the tides and the discovery that simplified equations can be used to describe deep sea tides will greatly improve modeling and other prediction programs.

Behavior of Marine Organisms

For years, biological oceanographers have been constrained from observing the behavior of live marine organisms by relatively crude collection techniques. Although millions of biological samples have been fished from the sea by conventional nets, traps, bottles, and trawls and placed in laboratory tanks and tubes for observation, many fragile, soft-bodied specimens are damaged and are unable to behave as they normally would in their natural habitats.

Several NSF-sponsored investigators are experimenting successfully with new techniques for observing without distorting or damaging the little known behavior patterns of zooplankton (floating or weakly swimming animals) in their natural environment.

William Hamner, University of California, Davis, is using scuba diving techniques for direct observation of the plankton community in the deep blue waters of the Florida Current near Bimini in the Bahamas, where water clarity often exceeds 150 feet. Visual observations of these exceedingly transparent organisms require a strong sunlight contrast, available in this deep blue environment.

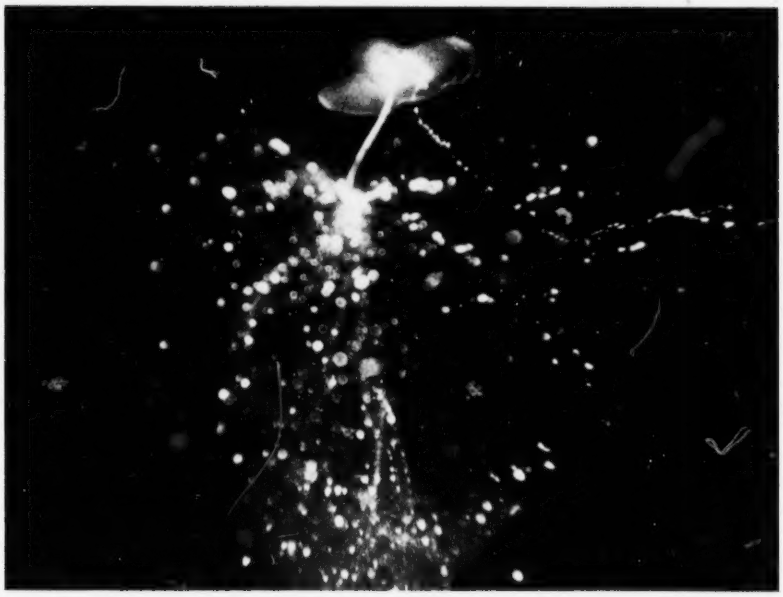
During more than 100 hours of underwater studies, Dr. Hamner's research team has observed remarkable biological phenomena for the first time, such as the feeding behavior of the pteropod *Gleba*, previously considered rare. This organism secretes a free-floating mucus web as wide as 1.2 meters in diameter to collect microplankton upon which it feeds. The *Gleba* maintains contact with this net with its extensile proboscis, while drifting plankton become enmeshed on its sticky surface, then it retrieves and ingests the entire mass of net and prey. Ten to 15 animals have been sighted simultaneously spreading their webs and fishing in this extraordinary manner. Previously, only 17 badly damaged specimens have been collected from the Mediterranean and Sargasso Seas.

Often, a behavioral sequence must be observed many times before it can be quantified. Another new technique of studying behavior of marine organisms in real life is that of using film holography. By taking a series of frames with a holographic micromovie, John Beers of the Institute of Marine Resources at La Jolla, and Michael Mullin of Scripps Institution of Oceanography can observe motions such as the "violent leap" of the copepod *Eucalanus* in three dimensions. The rapid and unpredictable motion of this *Eucalanus* is difficult to observe under standard microscopic conditions. With cineholography, Drs. Beers and Mullin plan to study feeding habits of copepods, including their selection of prey, methods of capture, and ingestion. Such information is important for understanding food chain dynamics and for developing computer models on the subject. Cineholography may become important for visualizing the ecologically important environment of zooplankton interactions.

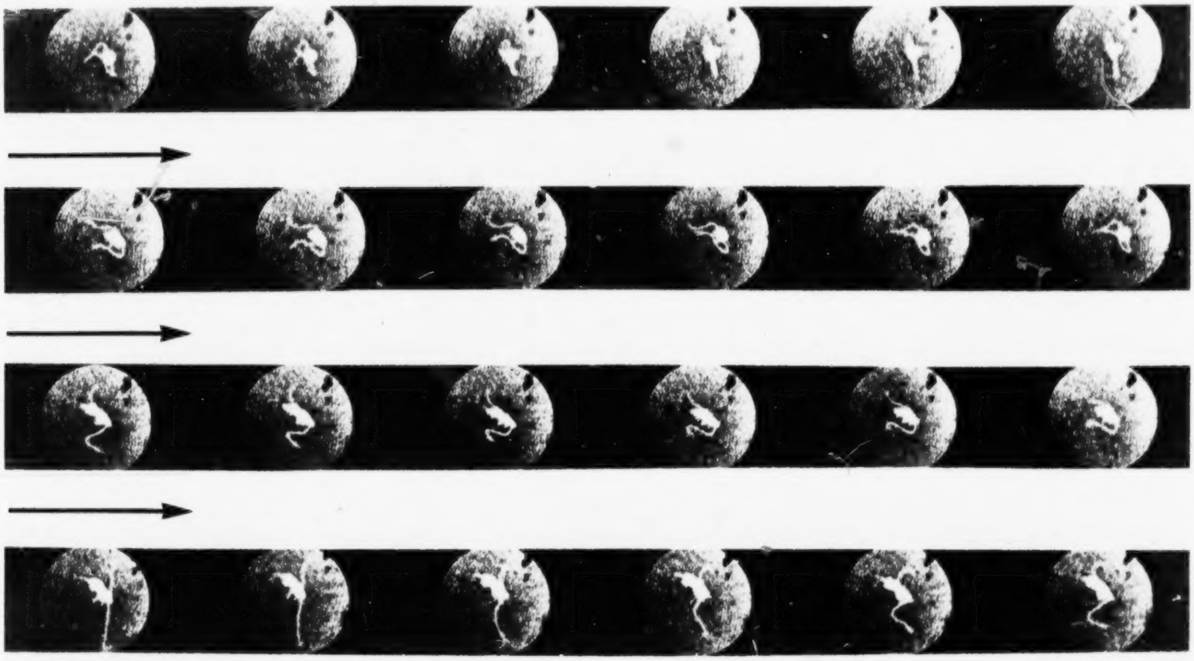
ENGINEERING

A basic motivation of an engineer is problem-solving. In the process, the engineer translates basic knowledge into practice and develops information or methodology where needed. Automobiles, the highways they drive on, waste treatment and disposal, color television, nuclear power stations, and the multitude of home appliances are only a few examples of the accomplishments of engineering. Though at one end of the gamut engineering interfaces with the pure sciences, two factors distinguish engineering research from the basic sciences. First, the work of engineering researchers is more closely tied to Government or industry programs; second, engineering projects must increasingly take into account a variety of public needs and concerns.

The Engineering Division supports research programs, primarily at uni-



Observed for the first time in motion, this fragile marine organism *Gleba* secretes a free-floating mucous web 1.2 meters in diameter to capture microorganisms on which it feeds; it then retrieves and ingests the entire net and prey.



START

The "violent leap" of the living marine organism *Eucalanus* is observed by a new technique for studying animal behavior--the holographic movie. This series of slides, shown at 20 millisecond intervals at a magnification of 1½X, focuses on the antennules of the microscopic animal. Movements of other appendages may be observed by examining the cineholograms at different depths of focus and with greater magnification.

versities, that are aimed at the generation of engineering information, development of methodologies for analyses and design, assessment of the effects of engineering projects, and the translation of basic technology into a form which can be used in practice. Early in fiscal year 1972, the division's activities in materials research — including research activities in both superhard materials for metal processing and biomaterials—were transferred to the newly formed Division of Materials Research (see pages 31 to 35).

A special activity in the general research support effort is the Research Initiation Program, which has been conducted since 1963. This program, designed to assist young engineering faculty members in establishing a research career, has been of particular value in engineering, where engineering faculties have undergone vast changes from the "art of engineering"-oriented groups of 25 years ago to highly versatile and research-oriented groups today. In 1972, a new feature was introduced in the program, "Option B," which made provision for a faculty member to spend two summers involved with industry, engineering offices, Government laboratories, or with a governmental unit of some level (city, county, State, etc.) in order to relate his research activities to real-world problems.

General research support covers all areas of engineering; many of those efforts are interdisciplinary. Among these organized areas of research are such diverse concerns as optical communications, advanced automation, chemical process dynamics, wind and natural disaster engineering, and planning and design of tall buildings.

Most of the research in the organized areas is still fairly fundamental in nature. But some of it is coordinated and oriented toward a particular problem area which may be of unusually important national significance; and some may be in areas of research that have not received sufficient attention for a variety of reasons. The latter includes, in particular, various problems related to the civil economy that are of importance to national productivity and competitive position.

Another feature of the Engineering Division's programs has been the university-industry workshops, involving representatives of organizations of both to define the present state of the art and to identify important future directions for research. During fiscal year 1972, workshops were held in:

- New Directions in System Science and Engineering — Theory and Practice
- Computers in Biomedicine
- Effects of Magnetic Fields on Communication Processes
- Industrialized Building Processes
- Lower Cost Housing Problems
- Engineering Software Coordination
- Glass Processing

The reports produced by these workshops are valuable reference documents to those interested in the area.

Ship Traffic Control

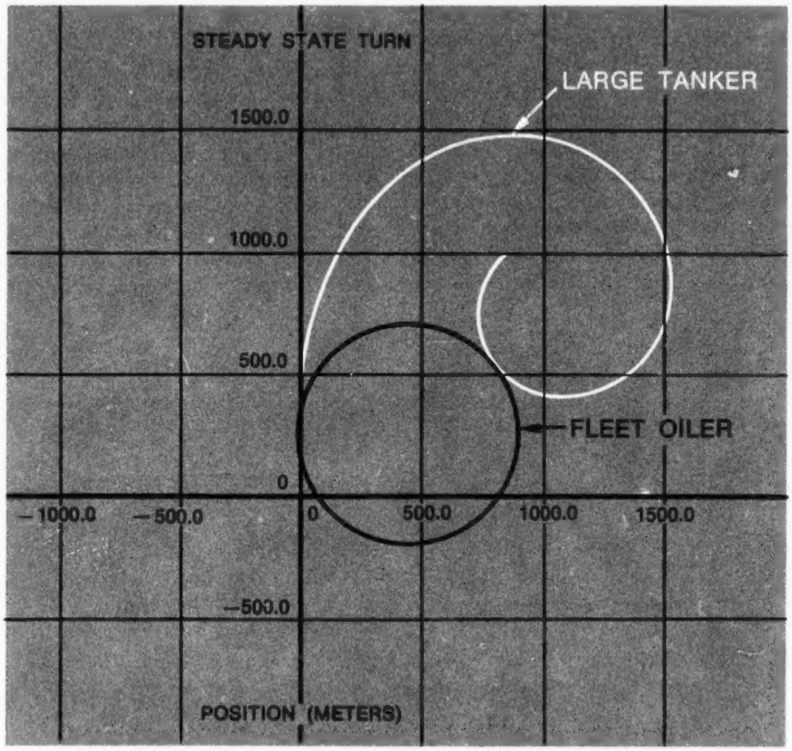
Each year there are about 9,000 marine accidents involving ships over 500 gross tons. Total claims arising from these accidents run at about $800 million per year. The admittedly very rough estimates include only the direct losses to the shipping industry. With the increasing size of bulk carriers and the rapid increase in the volume of trade in dangerous cargoes, marine accidents contain an increasing potential for imposing costs on third parties through pollution and damage to the ecology.

Moreover, a significant proportion of the accidents involve collisions in high traffic density areas—primarily harbors and their approaches. For these accidents, near valuable coastal zone regions, there is a particularly high peril of third party costs. At present, most of those costs are not borne by the shipping industry, and in some situations those unreturned costs can run several times the direct vessel and cargo losses. The time now appears ripe for the development of methods for preventing vessel collisions in harbors and their approaches. The basic idea is to adapt the most desirable elements of the familiar air traffic control system in developing a ship traffic control system. The initial phase of this work, which is being done by several investigators at the Massachusetts Institute of Technology, is limited to harbors and their approaches, but the idea could be extended to a worldwide routing system for the optimal scheduling of shipping.

Ship control schemes, of course, have many constraints different than those of air traffic control. Most of the existing supertankers have an operational speed of approximately 16 knots, and it takes an hour or more to reach that speed under full power settings and with ideal currents. Responses to a change of heading or an attempt to come to a full stop are sluggish. It should be no surprise, then, that vessel collisions occur when two shipmasters try to out-guess each other in a fog with tricky currents and no communication link open between the vessels.

J. N. Newman is concentrating his work on the effects of shallow and restricted water on ship hydrodynamics. A vessel with a 30-foot draft in an 80-foot harbor may be considered as being in deep water, but a 60-foot-draft ship in the same harbor is definitely in shallow water. Unfortunately, most of the available hydrodynamical data are applicable for deep water, so these important effects of finite depth, as well as the restrictions of channels are not available. Dr. Newman is translating ship maneuvering characteristics into needed hydrodynamical coefficients related to the environmental conditions.

In another allied project, J. Devanney and a Swedish visiting professor, N. Norrbin, are developing a traffic controller that can provide course and speed information to all ships within a specified area in real time. To do this, they must study the maneuvering characteristics of vessels, develop a computer program for simulating the vessel harbor system, and analyze various harbor control systems through that program. The heart of the computer program will be a description of ship maneuvering characteristics as a function of specified physical attributes of the vessel and of environmental conditions such as wind, current, and channel dimensions. This program will then take as input the description of the harbor under investigation, the physical characteristics and the initial conditions of the vessels in and approaching the harbor and their desired tracks, and also the characteristics of the harbor control scheme currently under analysis — including individual vessel-operator response. The program will be run for a number of combinations of vessel scenarios and harbor control systems, and the results analyzed to indicate for which control systems the expected reduction in collision incidence outweighs the cost of the system.



Based on actual maneuvering characteristics of two vessels—one a large tanker and the other a fleet oiler—this computer simulation shows their widely different responses to the identical command—a 30° steady turn.

Plant Growth

Scientists searching for a fundamental understanding of the process of growth in plants have turned in recent years to such engineering concepts as stress, plastic deformation, strain rates, and the effects of irreversible deformation. This led to the use of concepts from continuum mechanics in several key areas of plant physiology. Hypotheses formulated in terms of continuum mechanical concepts are now being tested in diverse experiments.

It has become clear that many continuum mechanical concepts and simulation techniques are applicable to behavior at different levels of plant organization—single cells, cells interacting in tissues, growth of a vast cell complex such as a whole leaf, and even the interaction of many organs in the growth of a whole tree. At the University of Massachusetts, Robert Archer, a civil engineer, and two plant physiologists, James Lockhart and Brayton Wilson, are studying three aspects of plant growth, namely vector growth field analysis, mathematical-mechanical models in tree growth studies, and cell wall mechanics. Vector growth field analysis is a first step in studying plant growth by providing a description of the distributions of growth rates in the organism being studied. Knowledge of this pattern can assist in subsequent analysis of the controlling factors of the growth and its results. The analysis begins with experimentally measured growth rates at a number of "marker" points in the organism; from these data it attempts to determine the velocity field—growth rates for different points on the surface being studied—and its properties as a function of space and time. To do this, Drs. Archer and Wilson develop mathematical mapping functions working directly from marker-point data on a photograph of a growing surface (such as a leaf). As a check on the method, it has been applied very successfully to analyzing the growth of specific leaves.

In the late 1800's and early 1900's, considerable work was done on the influence of stress on tree form. Much of this early interest in stress developed because of observations that stem form changed when trees were grown under conditions of low stress, and that stems become oval under unidirectional stress. In particular, tilting a stem results in compression wood being formed on the underside of the stem, causing the stem to bend back into a near vertical position.

Drs. Archer and Wilson have developed a mechanical-mathematical model to obtain stress distributions and changes in slope during compression wood formation as tilted young pine stems become righted. Using this model they hope to develop a simple "feedback control" model to relate gravitational stresses and wood reaction.

The development of the shoot and root systems of a tree depends on the interaction of the different organs within each system and also to interactions between the shoot and root systems themselves. Once established, the components of a tree may compete with each other for light and water and for internally supplied nutrients moving from other parts of the tree. Thus, the development of the whole plant is the final integration of the mechanical and biological processes that are acting at the cell, tissue, and organ levels of plant growth. Drs. Archer, Lockhart, and Wilson are now constructing computer simulations of growing shoot and root systems based on these interactions. Preliminary simulations using only numbers of organs (not including lengths or geometrical information) have been successful. Later, by suitable modification of variables, it should be possible to isolate the differences in growth algorithms that result in the characteristic forms of oaks, or elms, or pines.

Chemical Process Dynamics

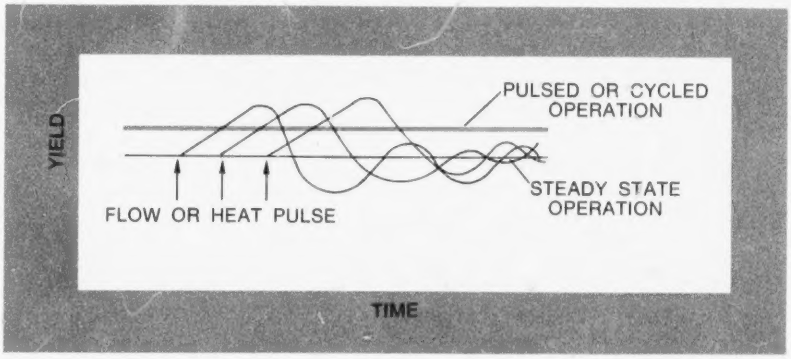
The techniques of continuous processing that evolved 20 to 30 years ago in the chemical and petroleum industries were linked to relatively slow mechanical control systems. As a result, stability became the ideal of large-scale plant operation, and traditional chemical process research has stressed steady-state analysis and operation of laboratory and plant equipment. Today, however, increasing attention in research is being directed at the dynamic phenomena that occur during startup, shutdown, and instabilities in plant operation. Theoretical studies indicate that prediction and control of these phenomena may provide the key to dramatic improvements in plant efficiency. In some cases, optimum production may even call for deliberate pulsing and cycling of operating conditions. Stimulated and aided by recent advances in applied mathematics and electronic computation, analytical research in this area stresses dynamic modeling and simulation of process units and configurations. The research utilizes high-speed electronic controls and specialized computational equipment for "real time" acquisition and analysis of data. Such equipment is now available at reasonable cost.

NSF supports several significant projects in this new field of chemical process dynamics. These include mathematical analysis of coupled systems and theoretical and computational investigations of chemical reactor control. Especially notable is the pioneering research of James Douglas at the University of Massachusetts. By applying the theory of nonlinear oscillations to analysis of chemical reactors, he has discovered that properly controlled periodic operation of chemical processes may enhance their performance well beyond conventional steady-state design. His current experiments with stirred-tank reactors, crystallizers, and pipelines under oscillating conditions show promising results.

Another key project is the work of Roger Schmitz at the University of Illinois. He is coupling experimental and theoretical studies of steady-state multiplicity, stability, and control in three types of continuous-flow chemical reactors. New computing equipment in his laboratory will be used for direct control and real-time simulation of experiments. Other grantees are investigating dynamic behavior of various specific types of plant equipment, such as distillation towers and extraction networks. Two of these principal investigators, Dr. Schmitz and Dale Rudd at the University of Wisconsin, are recent recipients of the Allan P. Colburn Award for significant research publications by young chemical engineers.

SOCIAL SCIENCES

Research supported by the Division of Social Sciences has as its primary goal the advancement of scientific knowledge about the interactions of men both with one another and with the physical and biological world and the functioning of institutions which men have created. This, of course, covers a very wide range of subject



The advent of better control systems and theory may make it possible to increase the productivity of chemical and petroleum processing plants by deliberately pulsing or cycling the operation.

matter, from the studies of human evolution by anthropologists, which form a bridge to the biological sciences, to the advanced models of the economy by econometricians which, similarly, link with the mathematical sciences. Particular emphasis is on the construction of scientific theory and improvement of research methods.

This year saw the establishment, as a separate program, of Research in Law and Social Sciences, an activity aimed at reexamining major components of the legal system in terms of social science findings. One interesting program now under way at Stanford University aims at determining if courts perform different functions in society depending on where they're located: urban versus rural, and in States with varying levels of economic development. If courts are found to be functionally heterogeneous in the sense they are optimized for different litigant classes and activities, the legal community will need to reassess its expectations of courts' social utility in various environmental settings.

The field of social psychology has also begun to shift directions, moving away somewhat from predominantly laboratory activities into field observations, and becoming involved more with allied professional disciplines. Examples of some types of field studies begun recently by social psychologists include the effects of crowding and overuse of State and national park facilities; the effect of hope on longevity in hospital patients; responses of teachers to verbal aggression in the classroom, including its impact on grades; verbal communication patterns of couples seeing marriage counselors; and more effective methods for maintaining medical regimens.

The methods of research by social scientists differ from those used by casual observers and commentators on social behavior in that they seek to establish reliable and reproducible results, quantified when possible. The objective is a cumulative growth of scientifically established knowledge.

Of special interest to the Foundation is work on science as a human activity and social institution. Science and technology are being studied as an economic force, as a social system organized both formally and informally, and as individual intellectual achievements. Historians and sociologists of science are trying to discern the degree to which major scientific accomplishments are dependent on personal characteristics of outstanding scientists or on the intellectual "climate" of the time.

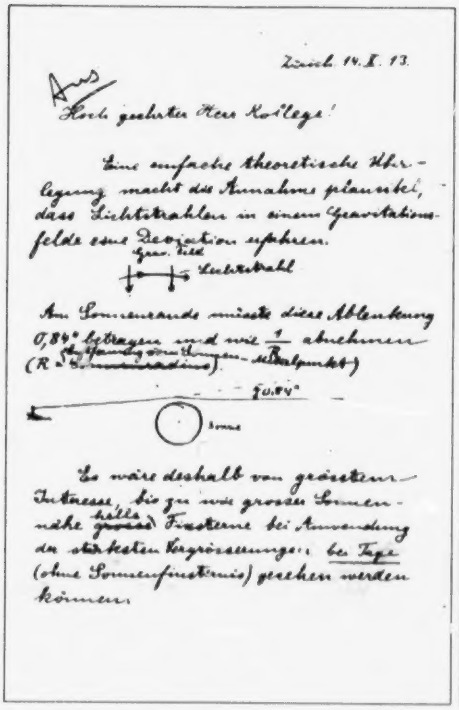
Economic Diffusion of Science

Economists have been engaged for more than two decades in an effort to expand our knowledge of how new processes and products are invented, commercialized, and accepted. The nature of the diffusion process in the more research-intensive "science-based" industries is the subject of an important ongoing study by Edwin Mansfield of the University of Pennsylvania. Specifically, Dr. Mansfield disputes the view of some distinguished scientists and engineers that the diffusion process goes on differently in such industries than in others. To help resolve this question, he has carried out a very detailed study of the rates of diffusion of 18 important process innovations in one of the nation's most research-intensive industries, chemicals. For each innovation, data had to be gathered concerning the rate of growth of chemical firms using the innovation, the growth of each chemical firm's output produced with the innovation, and the growth of the chemical industry's total output produced with the innovation.

A number of significant conclusions emerged from this inquiry. First, it appears that the same sort of model applies very well in this science-based industry as in the less research-intensive industries. The pattern and course of growth in the number of firms using an innovation and in the increase of output produced with the innovation is much the same. And the profitability of the innovation is, as before, a key determinant of the rate of diffusion. Second, although the same kind of model seems to fit, the parameters in the chemical industry differ from those in less research-intensive industries. Thus, when the profitability of the innovation and the size of the investment are held constant, innovations seem to spread more rapidly in the science-based chemical industry. Third, there is evidence that innovations tend to spread more rapidly if the firms in the industry are relatively equal in size, a finding which has special interest from the point of view of industrial organization and public policy. Fourth, Dr. Mansfield investigated the determinants of various other measures of the rate of diffusion in addition to the rate of imitation. His results indicate that the same sorts of factors are operative. Fifth, he looked in detail at the characteristics of the firms that have been relatively fast—or relatively slow—to adopt each of these innovations, embodying the results of explanatory econometric models. Although his present models offer some basis for technological forecasting, Dr. Mansfield emphasizes that we need to know much more about the mechanisms and the costs of transferring technology from organization to organization and from country to country.

The Scientific Development of Albert Einstein

Twenty-two years ago, Albert Einstein challenged historians of science to find "a means of writing (history of science) . . . which conveys the thought processes that lead to discoveries." Recent studies of Einstein's papers by Gerald Holton of Harvard University have enabled that historian of physics to provide new insights into one of the great conceptual revolutions of all time—the development of relativity theory.



Zürich 14. X. 13.

Aus

Hoch geehrter Herr Kollege!

Eine einfache theoretische Überlegung macht die Annahme plausibel, dass Lichtstrahlen in einem Gravitationsfelde eine Deviation erfahren.

Grav. Feld

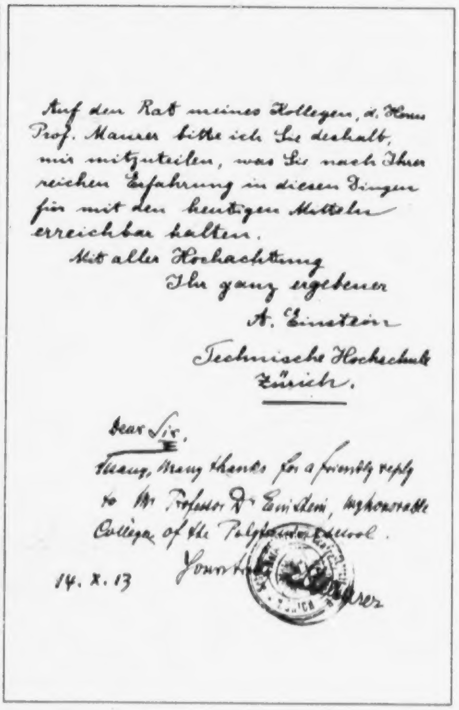
Lichtstrahl

Am Sonnenrande müsste diese Ablenkung 0,84" betragen und wie $\frac{1}{R}$ abnehmen (R = ~~Sonnenradius~~ Entfernung vom Sonnen-Mittelpunkt).

0,84"

Sonne

Es wäre deshalb von grösstem Interesse, bis zu wie grosser Sonnennähe ~~grosse~~ helle Fixsterne bei Anwendung der stärksten Vergrösserungen bei Tage (ohne Sonnenfinsternis) gesehen werden können.



Auf den Rat meines Kollegen, d. Herrn Prof. Maurer bitte ich Sie deshalb, mir mitzuteilen, was Sie nach Ihrer reichen Erfahrung in diesen Dingen für mit den heutigen Mitteln erreichbar halten.

Mit aller Hochachtung
Ihr ganz ergebener
A. Einstein

Technische Hochschule
Zürich.

Dear Sir,

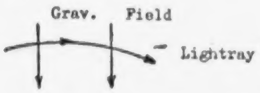
Many, Many thanks for a friendly reply to Mr Professor Dr Einstein, highhonorable Colliega of the Polytechnic School.

Yours [illegible] Maurer

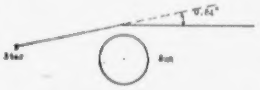
14. X. 13

Albert Einstein to Hale, October 14, 1913
*My very dear Colleague:

A simple theoretical consideration makes plausible the assumption that light rays experience a deviation within a gravitational field



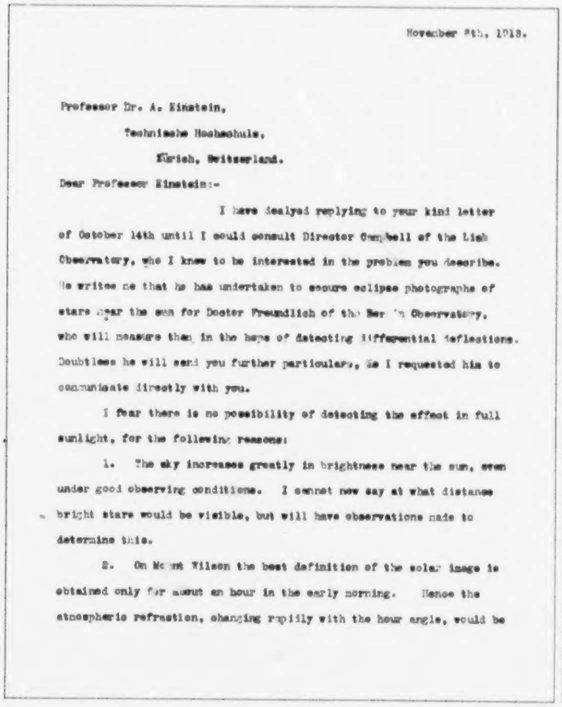
On the edge of the sun the deflection should be 0.84" and as $\frac{1}{R}$ diminish (R = Distance from the center of the sun)



Therefore it would be of the greatest interest to know within how great a proximity to the sun bright stars could be seen by daylight [without a solar eclipse] with the help of the largest magnification.

Upon Prof. Maurer's recommendation I write to you, and beg you to let me know what the chances are to obtain results with the present-day equipment and your vast experience in this field.

*Addressed to Prof. George E. Hale, Pasadena, Calif., by Dr. Albert Einstein, Zürich, Switzerland.
The Hale Papers. Translation by Erwin Morkisch.



November 8th, 1913.

Professor Dr. A. Einstein,
Technische Hochschule,
Zürich, Switzerland.

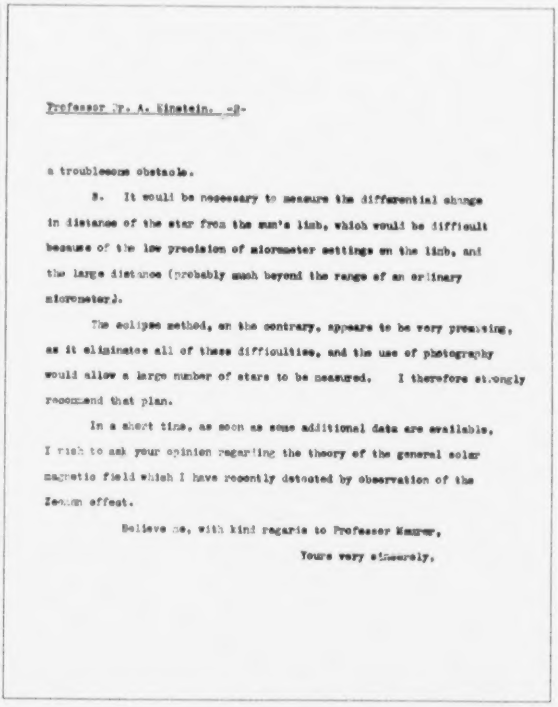
Dear Professor Einstein:-

I have dealyed replying to your kind letter of October 14th until I could consult Director Campbell of the Lick Observatory, who I know to be interested in the problem you describe. He writes me that he has undertaken to secure eclipse photographs of stars near the sun for Doctor Freundlich of the Berlin Observatory, who will measure them in the hope of detecting differential deflections. Doubtless he will send you further particulars, as I requested him to communicate directly with you.

I fear there is no possibility of detecting the effect in full sunlight, for the following reasons:

1. The sky increases greatly in brightness near the sun, even under good observing conditions. I cannot now say at what distance bright stars would be visible, but will have observations made to determine this.

2. On Mount Wilson the best definition of the solar image is obtained only for about an hour in the early morning. Hence the atmospheric refraction, changing rapidly with the hour angle, would be



Professor Dr. A. Einstein. -2-

a troublesome obstacle.

3. It would be necessary to measure the differential change in distance of the star from the sun's limb, which would be difficult because of the low precision of micrometer settings on the limb, and the large distance (probably much beyond the range of an ordinary micrometer).

The eclipse method, on the contrary, appears to be very promising, as it eliminates all of these difficulties, and the use of photography would allow a large number of stars to be measured. I therefore strongly recommend that plan.

In a short time, as soon as some additional data are available, I wish to ask your opinion regarding the theory of the general solar magnetic field which I have recently detected by observation of the Zeeman effect.

Believe me, with kind regards to Professor Maurer,

Yours very sincerely,

The Einstein collection includes thousands of private papers, letters, notebook, and scientific manuscripts. While some of the letters have appeared in various collections, the great bulk of the material has never been published. The papers include material documenting some of the factors contributing to the development of a scientific genius. They tell of a child whose inability—or unwillingness—to speak until the age of three led him to develop an extraordinary capacity for nonverbal conceptualization. In the view of Dr. Holton, such use of abstract concepts, rather than words, persisted into Einstein's adult life. For the great scientist noted, "the words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought." He said that he formulated his ideas in "physical entities . . . certain signs and more or less clear images which can be 'voluntarily' reproduced and combined."

The controlling factors of Einstein's development, Dr. Holton has pointed out, include early training, family influences, personality, philosophical outlook, and placement among colleagues. In later years, Einstein said that two objects played a special inspirational role in his life. One was a geometry book that sent his mind racing off in new directions as a boy. The other was a compass: The mysterious, all-pervading "field" of magnetic force that controlled the compass needle fascinated the child.

This fascination ultimately led him to challenge contemporary concepts of magnetic fields and to develop an entirely new formulation of gravitational fields. Dr. Holton believes that Einstein's habit of thinking in concepts rather than words played a key role. He cites a comment by Einstein to a friend when they were discussing the genesis of his ideas. "These thoughts," he said, "did not come in any verbal formulation. I rarely think in words at all. A thought comes, and I may try to express it in words afterward."

This habit of conceptualization made it easier for Einstein to break free of the methods of thought that prevented his contemporaries from recognizing the limitations of the concepts of space, time, light, mass, and energy that are rooted in the limited capabilities of direct human experience.

Evaluation of Accomplishment

Why do women seem to achieve less success than men? One reason commonly given is that of male prejudice against women and subsequent devaluation of female accomplishments. It is also possible that women themselves, although the targets of prejudice, may share the attitudes of the dominant male group. This underevaluation could reduce women's efforts to try to achieve and thus foster an actual lack of achievement.

A recent study by Sara Kiesler at the University of Kansas has shown that under certain circumstances women value the professional work of men more highly than that of women. She asked 120 college women to evaluate abstract modern art paintings by unknown artists. Fictitious biographies of the artists, half portraying males and half females, accompanied the slides of eight paintings. The paintings were identified as either a contest entry or a recognized winner. Students commented on the technical competency, creativity, quality of painting, emotional impact, and the painter's probable artistic future.

Responses to questions revealed that paintings ostensibly entered by males (but not yet evaluated by experts) were judged by the subjects in the study to be better than identical ones credited to female artists. Evaluations of paintings which had been judged winners by the experts, however, were evaluated by the subjects to be equal regardless of the painter's sex.

Bias against women occurred in evaluations of technical competence and predictions of the artist's future, areas in which men are expected to excel. Evaluations of creativity, emotional impact, and quality revealed no discrimination against women. This finding is consistent with common sex stereotypes which hold that although women may be expected to be less competent and have fewer accomplishments than men, they are not expected to be less creative. Because the paintings were abstract and difficult to judge on the dimensions requested, it is probable that evaluations reflect attitudes held prior to the study.

These findings have far-reaching implications. Although women favorably evaluate females' work which has received special distinction, lacking such information, they judge work by women to be inferior to equivalent work of men. It would thus be difficult for women to achieve recognition when placed at the competitive disadvantage revealed by these data. To appreciate the strength of this finding fully, one must recognize that it is based on a sample of women exclusively, a group which might be considered more sympathetic than a mixed one or one composed of all men.

MATERIALS RESEARCH

The field of materials is a fascinating amalgam of ancient and modern. Archeological times are marked by such terms as "Bronze Age" and "Stone Age," but the relatively modern systematic variation and control of properties has been studied scientifically for only a few decades. Perhaps the first great step forward in sophisticated understand-

This correspondence between Einstein and American astronomer George Ellery Hale discusses an early (and not quite correct) result of general relativity. The letters were found by Charles Weiner (of the American Institute of Physics) at the Hale Solar Laboratory in Pasadena, Calif. (Reprinted with permission of the Carnegie Institution of Washington and the Einstein Estate) ing of structure-sensitive properties came with the postulate of "the dislocation" independently by Orowan, Polanyi, and Taylor in 1934. The dislocation, or misregistry in the crystal lattice, is only one of a number of types of defects. Other defects were soon proposed and the number grew enormously; the best experiments varied one type of defect independently of all others to isolate the resulting property changes.

After World War II, the remarkable acceleration in electronic materials came when zone refining made a suitably pure host lattice available for many interesting variations in composition and resulting properties. In addition, theory was able to maintain a predictive role in these materials and, consequently, the electronics industry ran away in sophistication from the traditional industries, which depended on less well understood mechanical and chemical properties.

About 1960, a major decision was reached to attempt to improve our knowledge of materials by providing significant research support at selected universities. The result was the establishment of materials science centers by the Advanced Research Projects Agency (ARPA), Atomic Energy Commission, and National Aeronautics and Space Administration. Throughout the 1960's, much outstanding work in materials was sponsored in individual grants both from NSF and other agencies. Efforts are now being made to strengthen programs in the engineering aspects of materials while further extending the strong science base already present to include studies of nonelectronic properties.

In 1970, NSF was asked to assume sponsorship of the 12 ARPA laboratories, and also of the Air Force-supported National Magnet Laboratory (NML) at the Massachusetts Institute of Technology. In 1971, NSF's Division of Materials Research was created with responsibility that included the former ARPA laboratories (now called Materials Research Laboratories, or MRLs), the NML, and NSF's existing grants in solid-state and low-temperature physics, solid-state chemistry, and engineering materials. Polymer science was added as part of the Solid State Chemistry Program. The Foundation now provides over 50 percent of the Federal support for materials research at U.S. educational institutions.

The National Magnet Laboratory is unique in this country. It exists to provide ultrahigh magnetic fields for all qualified users and to develop new, advanced magnets. Meanwhile, the laboratory staff conducts research in magnetic phenomena and provides a number of innovative ideas for applications of very high and very low magnetic fields.

Over the past year, the Solid State and Low Temperature Physics Program continued and strengthened its support in such areas as resonance physics; superconductivity; magnetism; and electronic and optical properties of metals, semimetals, and insulators. Also, in response to a number of proposals received and the recommendations of reviewers, research in surface physics, liquid crystals, and the application of light scattering techniques to various fields was emphasized. Activity increased, too, in low-temperature physics; this well-established area now appears to have great relevance to some of the most recent and interesting aspects of surface physics.

A broad range of topics was funded in the Solid State Chemistry and Polymer Science Program, ranging from the synthesis of new polymeric and inorganic substances to the detailed structure determination of complex polymers and intermetallic compounds. In general, the chemical synthesis was directed toward novel methods to prepare polymers with improved properties. In the solid-state chemistry area, new compounds were prepared using high-pressure techniques. In the continuing effort to understand the structure/property relationships which are essential to the ultimate improvement of materials' performance, new methods of polymer characterization are being investigated using laser Raman spectroscopy, dynamic X-ray diffraction, and new rheological instrumentation. Similar refinements of analytic procedures for the inorganic systems are being encouraged, and careful work involving effects of impurities and defect structures is continuing. Theoretical work, including configurational statistics of polymer chains and electronic band structure of inorganic systems, is a necessary underpinning to the experimental program in solid-state chemistry and polymer science.

The Engineering Materials Program supports research in the following areas: materials preparation and characterization; electronic, magnetic, and optical behavior; mechanical behavior; physical and extractive (chemical) metallurgy; materials processing; and biomaterials. Continued growth is expected for programs in materials processing and process characterization (which includes metal removal through cutting and grinding, powder conversion, and forming and joining) as well as for nondestructive characterization and design of failure-free materials.

Magnetic Filter

At the Francis Bitter National Magnet Laboratory at MIT, some noteworthy advances in the art of purification and filtration using magnetic fields have emerged as a byproduct of an esoteric physics research project—a search for the magnetic monopole. The monopole is an elementary particle whose existence had been suggested by Dirac, but which has as yet not been found. It was hypothesized that these high-energy particles might enter the environment of the earth in cosmic ray showers, be subsequently moderated by the oceans, and ultimately be trapped by the magnetic constituents of the ocean bottom sediments. But the job of separating the magnetic components of the sediments from the nonmagnetic was unfeasible with the magnetic separators available when Henry Kolm began his research project a few years ago. To overcome that limitation, he developed a new type of magnetic filter that could handle large volumes of sediments at rapid flow rates.

His filter employed a matrix of steel wool magnetized in a high magnetic field. The combination of high field gradient and high background field acts to exert strong forces on the magnetic particles of the sediments and trap them on the strands. The relatively open nature of the structure makes for low flow resistance to the background slurry and, consequently, high filtration rates. Flow rates of 30 gallons per minute per square foot are typical and are by no means an upper limit.

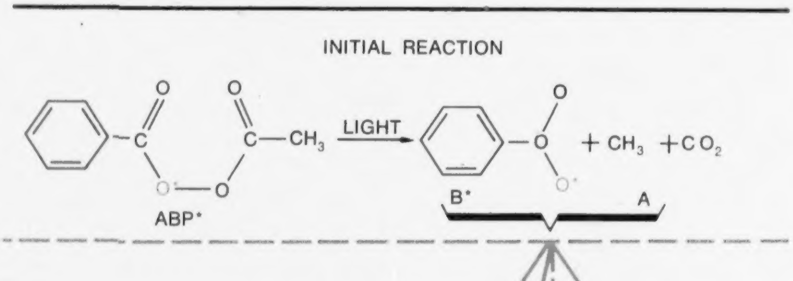
Although basically simple in concept, the new filter has found application far beyond its original purpose. It proved to be a readymade solution to the problem of removing the yellowish titanium dioxide impurities in kaolin, a clay product used for white paper coating, and replaced a more expensive chemical form of treatment.

It was at once clear that the filter was a potentially useful tool for separating out fine weakly magnetic matter. What was not immediately evident, and came somewhat as a surprise, was the discovery that it could be applied to the filtration of nonmagnetic matter, including bacterial and algal matter. This process uses a finely divided iron oxide seed material to scavenge the nonmagnetic matter, which presumably attaches itself to the seed by chemical bonding mechanisms. The combination particles are then removed magnetically. In some tests conducted on water from the Charles River Basin, following a single pass through the separator, the coliform bacterial count was reduced from something on the order of 10,000 to zero; biological oxygen demand, suspended solids, and turbidity were also greatly reduced. Significant reductions in these indicators were also obtained with some samples of primary sewage effluent, indicating that magnetic treatment can have a place in more sophisticated treatment schemes of the future. The treatment of industrial effluents appears to be one of the promising areas for immediate application. As an outcome of this work, a team of Magnet Laboratory scientists, H. H. Kolm, E. Maxwell, J. A. Oberteuffer, D. R. Kelland, and C. de Latour, are investigating these and further applications of the magnetic separation process under sponsorship of the Foundation's Research Applied to National Needs program.

Preparation of Pure Compounds

Faced with a reaction that refuses to yield the desired end-products, organic chemists sometimes dream of holding the reacting molecules tight with microscopic tweezers and forcing them to give the right products. While such "tweezers" are obviously a fantasy for reactive molecules moving freely in fluid solutions, in solids the surrounding molecules can "hold" reacting molecules and control their motion so as to give products quite different from those obtained in fluids. Although instances of the use and study of such control by chemists have been rare, there are many practical examples of organic reactions that occur under the influence of very viscous or rigid surroundings. These include reactions in biological membranes and in enzymes, reactions causing decay of frozen foods, and reactions involved in the synthesis and in the fatigue and aging of plastics and other synthetic and natural polymers.

There are many instances in which groups that would be of identical reactivity in solution are different in the solid state. For example, acetyl benzoyl peroxide (ABP) is decom-



Two of the reaction products of this ABP molecule react with each other to form new compounds. Experiments in which one of the available oxygen atoms is distinguished from the other by a slight weight difference reveal that in liquid either of the two oxygens will react with equal probability; in solid, the reaction occurs with the oxygen that held the original ABP halves together.

posed by light into three fragments: a carbon dioxide molecule and two very reactive free radicals (A and B). In fluid ABP these two radicals undergo a bewildering variety of further reactions to give more than a dozen low-yield products. In solid ABP, however, only two products are formed.

The unique features of the solid state reaction are most evident by comparing the product from coupling the two radicals, A and B, in the solid with that from the same reaction in solution. When the oxygen atoms of radical B are made distinguishable by incorporating a heavy oxygen isotope (O^*) in the oxygen bridge of ABP, we can show that coupling in solution occurs through the two oxygens of B with equal probability, as would be expected from the symmetry of the radical. J. Michael McBride at Yale University has shown that the solid can hold radical B in a way that preserves a difference between its oxygens, and the great majority of the solid state coupling occurs through the oxygen which initially bridged the fragments in the ABP molecule. In this manner, products consisting essentially of a single species can be obtained without the additional process of purification needed when the reaction results in several species.

Homogenization of Powder Compacts

Powder fabrication could become a superior method of producing many metals and alloys. Some techniques have been employed for many years, and the powder fabrication of mill shapes (sheet, forgings, bars, extrusions) is currently receiving considerable attention. The advantages of powder fabrication are: (1) a minimum amount of metal working and material loss in achieving a final product; and (2) a great potential for producing structures not attainable by casting techniques. The major deterrent to the development of this process lies in the economics of producing the high purity powders necessary as starting materials. Moreover, alloys are usually desired, and alloy powders produce the greatest problem.

Numerous investigations have been carried out on the blending of elemental powders to achieve the desired alloy composition, followed by a long diffusion treatment at high temperature to achieve the required alloy homogeneity. But such diffusion treatments are economically unfeasible. Thus, the basic materials problem to be solved is to devise a means of predicting the effects of fabrication on the homogenization process. This would permit tailoring the fabrication conditions to minimize the time needed to homogenize the material. Basic research in diffusion theory in past years, coupled with more recent developments in numerical methods and computer techniques, have provided a means of analyzing the homogenization and fabrication process.

Both mathematical model analysis and experimental studies have been carried out under NSF support by R. W. Heckel (at Drexel University and more recently at Carnegie-Mellon University) on the homogenization behavior of compacts in two-metal alloy systems. These studies have shown the value of analyzing the homogenization problem in terms of specific parameters such as diffusion coefficients and solubilities for each phase, powder particle size, compact composition, and homogenization time. It has been shown that the accuracy of the model improves as the blend approaches an ideal distribution of particles. Moreover, the results to date have shown that even in poorly blended compacts, the model can be used to predict the relative effects of changes in processing parameters and conditions necessary for the most effective homogenization process.

The analysis is general and can be extended to investigate the diffusion bonding of metals, the structural stability of high temperature alloys, the stability of composite materials, and the formation of coatings for elevated temperature oxidation protection.

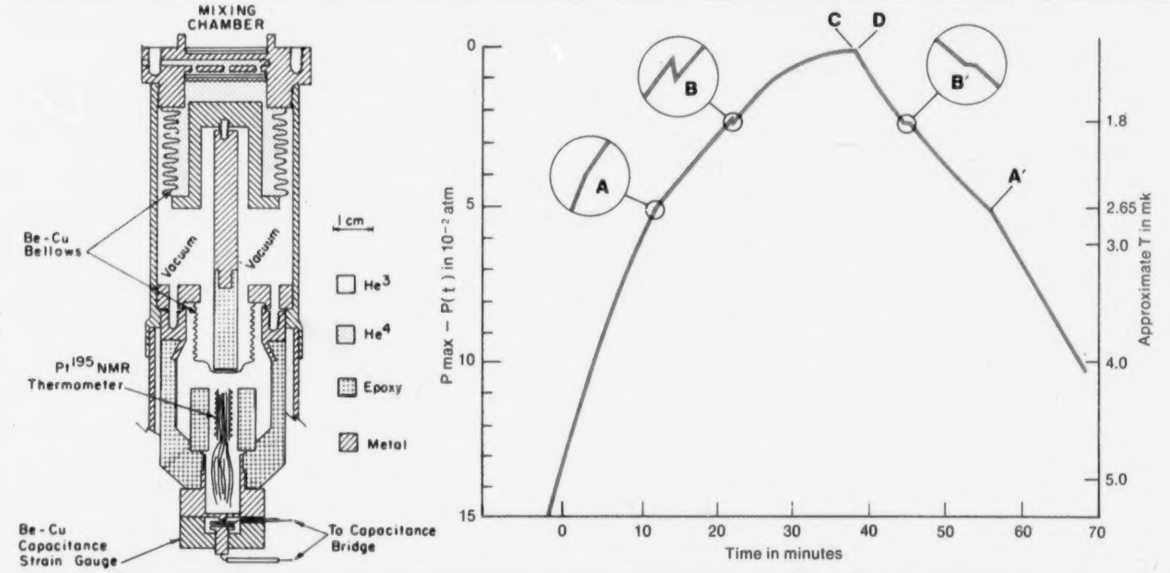
Ultra-Low Temperature Nuclear Phase Transitions

Individual atomic nuclei possess a spin and, consequently, a magnetic moment which enables them to orient themselves in a magnetic field. Thus, individual nuclear moments can, under certain conditions, give rise to magnetic effects similar to, though much weaker than, those produced by electrons in solids. The effects of this nuclear magnetism are best observed at ultra-low temperatures. The less abundant, natural isotope of helium (He^3) is a good example of such a nucleus which has a rather sizable nuclear magnetic moment. In addition, it is of special interest since it is a simple nonreactive system with no electronic magnetism; thus the magnetism of the nuclei will play a dominant role.

The magnetic properties of both liquid and solid He^3 at ultra-low temperatures depend directly on the way the nuclear spins couple to each other and to the outside world through the electronic system in which they are located. Some physicists expected a specific arrangement of nuclear spin coupling in He^3 at temperatures about 2 milli-degrees Kelvin in the solid, even in the absence of an applied magnetic field. This expected arrangement of a type known as anti-ferromagnetic would consist of alternating directions for these nuclear spins.

However, no direct experimental evidence of any spontaneous regular ordering of the nuclear spins in He^3 had been observed. During fiscal year 1972, a low-temperature physics group at Cornell University made important new observations which enhance our understanding of nuclear magnetic coupling in He^3, by using a pressure cell proposed in 1950 by a Russian scientist, I. Pomeranchuk. He suggested that one could achieve extremely low temperatures by squeezing a mixture of solid and liquid He^3. The observations by the Cornell group were made at ultra-low temperatures with the apparatus shown. A moderate He^4 pressure in the upper chamber is used to solidify the He^3 in the lower chamber. The He^3 melting curve can then be studied precisely down to temperatures as low as 2 milli-degrees Kelvin. Any nuclear magnetic ordering would show up as a pressure anomaly at low temperatures in such a cell. Using this apparatus, D. D. Osheroff, R. C. Richardson, and D. M. Lee have recently discovered two heretofore unobserved phase transitions in pure He^3. These transitions manifest themselves as abrupt pressure changes, producing kinks in the temperature-pressure curve, both during pressurization and subsequent depressurization of the cell.

This result is the first evidence for phase transitions in a mixture of solid and liquid helium. Further experiments carried out at Cornell indicate that at these pressure anomalies, the magnetic properties of the liquid part of their sample changed dramatically. Experiments do not yet confirm the existence of anti-ferromagnetism in the solid. They do indicate the presence of some kind of spin ordering, as yet not fully explored, which is taking place in the liquid. Related work is presently under way in several laboratories to gain a fuller understanding of these newly observed transitions, one or both of which may be the only known examples of nuclear magnetic ordering.



Using the pressure cell on the left, in which very low temperatures are attained, Cornell scientists discovered two pressure anomalies (during both pressurization and depressurization) that correspond to what may be nuclear magnetic ordering.

National and International Programs

The Directorate for National and International Programs has the responsibility for agency management of those major programs and research centers of the Foundation having one or more of the following characteristics:

- significant operational content;
- major logistic requirement;
- substantive and continuing international involvement
- facilities for joint use of academic investigators;
- coordinated and continuing scientific information activity;
- major computer science involvement.

Among the diverse activities which are administered by this directorate are three major oceanographic programs; two large polar research and support operations; five national observatories and centers; the Foundation's programmatic computer activities; the science information service; and the coordination and support of NSF international research involvement.

Table 4
National and Special Research Programs Awards
Fiscal Years 1970, 1971, and 1972
(Dollars in millions)

	Fiscal year 1970		Fiscal year 1971		Fiscal year 1972	
	Number	Amount	Number	Amount	Number	Amount
International Biological Program	24	$ 4.00	37	$ 7.50	38	$ 9.44
Global Atmospheric Research Program	19	1.49	31	1.90	37	2.39
International Decade of Ocean Exploration	0	0	44	15.00	102	19.67
Ocean Sediment Coring Program	25	6.55	8	7.13	8	9.26
Arctic Research Program	0	0	32	2.00	61	3.54
U.S. Antarctic Research Program	128	7.41	121	7.76	139	27.00
Oceanographic Facilities and Support	31	7.60	21	8.57	65	14.52
1973 Solar Eclipse Logistic Support	0	0	0	0	0	.06
Total	227	$27.05	294	$49.86	450	$85.88

NATIONAL AND SPECIAL RESEARCH PROGRAMS

INTERNATIONAL BIOLOGICAL PROGRAM*

The International Biological Program (IBP) for which the National Science Foundation is the lead agency in the United States, was initially organized to study the biological structure and function of ecosystems and determine man's relation to them. One of the goals is to predict the consequences of possible natural or man-induced changes brought on specific ecosystems.

Since these studies had to be undertaken on a large scale, it was necessary to mobilize large numbers of scientists from various fields. The research work was organized into large projects within five distinct kinds of life zones called biomes—grassland, desert, coniferous forest, deciduous forest, and tundra.

Most of the work on these ecosystems accomplished to date has been involved with the production of models and the development of the necessary basic information to verify those models. Substantial progress has been made during this past year in development of validated segments of these models concerning interrelationships between plants and animals, for instance. Some semblance of predictability is beginning to emerge, though as yet no predictive model for an entire ecosystem exists.

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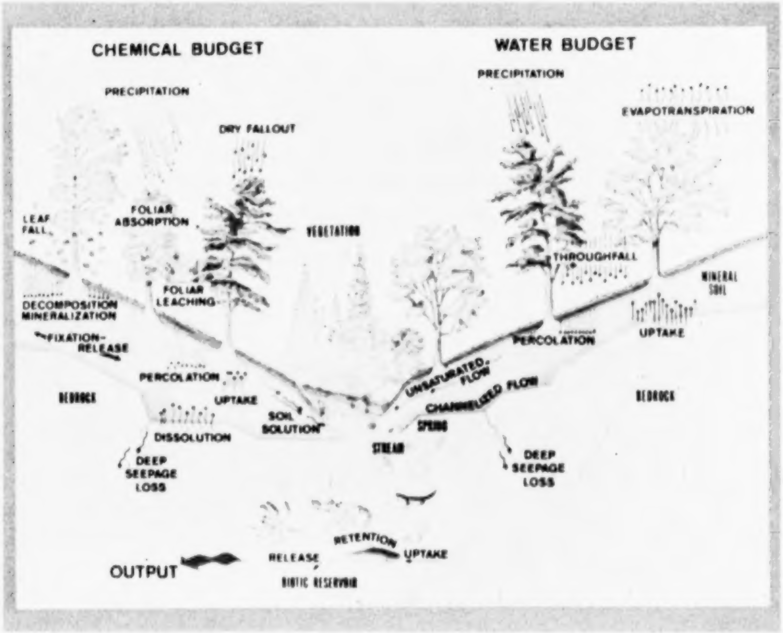
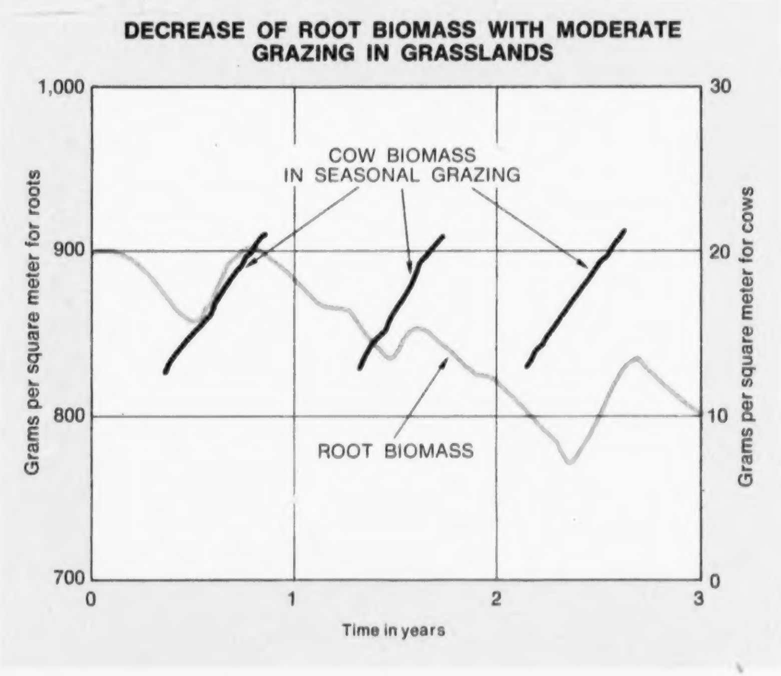
* Although administered by the Research Directorate, IBP is included here because of its identification as one of the Foundation's National and Special Research Programs.



This diagram of the hydrologic and chemical cycles of a typical Eastern deciduous forest watershed shows the interactions between soil, vegetation, and water.

Researchers are beginning to observe similar phenomena among the various biomes. Animal populations are now being considered as controlling agents in every type of ecosystem, rather than as links at the top of the energy flow. Another point was raised in grassland areas, where researchers observed that soil phosphates appear to be greater in more arid regions of the biome and at certain seasons. In other words, there are more stores of phosphates in areas of less precipitation and during the late fall and winter when plants are not absorbing the phosphates. This raises questions on a possible relationship throughout all biomes among soil phosphate deposits, amounts of pre-

Much of the value of the modeling work to date has been heuristic, and scientists have had to synthesize meaning out of what might otherwise appear to be an assortment of nonrelated data. For instance, scientists working on grasslands were able to predict from modeling efforts that the root biomass would diminish with moderate or heavy grazing. This suggested that the grazing animals, though not particularly significant in terms of flow of energy in the food chain, were very important in terms of controlling factors with possible effects on the diversity and distribution of vegetation. Another example of amassing various data into significant meaning can be seen in the desert biome, where scientists observed a strong interaction between the production of annual seed-bearing plants and populations of birds and mammals. Since nonliving factors such as temperature, water, and minerals affect the seed production, scientists drew a formerly undefined concept that nonliving factors ultimately may control densities of animal populations.



A 3-year computer simulation of an area below ground in the grasslands shows a decrease of root biomass from about 900 to 800 grams per square meter with moderate grazing by cattle. During the time of grazing each season, the cattle biomass increased approximately 12 to 21 grams per square meter. The decrease in the root biomass corresponds to a long-term decrease in the vegetation above ground.

cipitation, and the whole rhythmic pattern of biological changes with changing seasons.

Another project included in the U.S. section of IBP is the Conservation of Ecosystems in which researchers are cataloging private natural areas such as tall grass prairies on private ranches, natural rivers not yet harnessed for power, and private seashore areas not yet modified or developed.

The Human Adaptability Studies include research of the genetics and nutrition of certain Indian tribes of North and South America. Studies on the patterns of moving from one village to another, mating, and producing offspring in the large South American Yanomama tribe are producing evidence that may revise theories of heredity and gene flow from an assumption of nonrandom pattern of gene flow to that of a random flow. Archaeological and ecological studies tracing populations of the Aleutian Indians may change theories of the migration of people to North America from the mass migration concept to that of a very gradual population "drift."

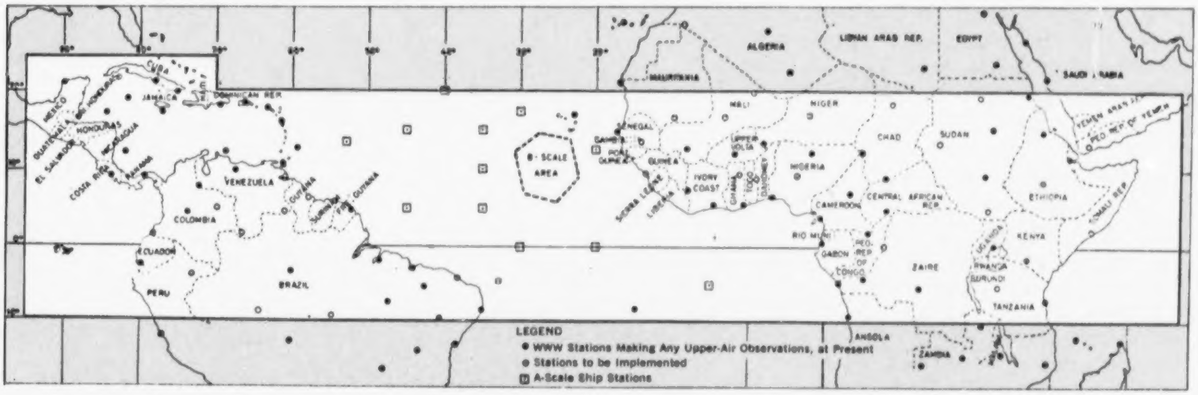
During the past year, a large research project was started on biological control of pests. Under the direction of Carl Huffaker, University of California, Berkeley, some 19 institutions and several hundred scientists are working toward establishing tactics for regulations of pest populations. The project uses an integrated approach to analyze crop ecosystems, insect pests that feed on these crops, and predators and diseases that affect the pests.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM *

During the year, the greatest emphasis, nationally and internationally, continued to be concentrated on planning and designing the GARP Atlantic Tropical Experiment (GATE) to be conducted in the summer of 1974. The objective of GATE is to extend our knowledge of the meteorological aspects of the equatorial belt, essential for a better understanding of circulation patterns of the entire earth's atmosphere.

Work on Observing Systems Simulation Experiments (OSSE) has been delegated to NCAR. These experiments are designed to assess and improve individual observing systems by means of numerical simulation using global circulation models. In a set of numerical modeling experiments in which temperatures are updated every 12 hours, it has been shown that a wind field can be produced. The accuracy of this wind field is a function of the accuracy of the temperature data and the frequency with which it is updated. On the other hand, if the wind field is periodically updated, then the temperature field can be produced. Temperature updating is extremely important in forecasting wind fields on a global scale. In the tropics, wind observations are the most important variable to be measured. When tropical winds are updated at a few, but not all, levels in the model, the forecast results are observed more rapidly in the vertical than in the horizontal direction.

One of GARP's objectives is to understand the factors that determine the statistical properties of the general circulation of the atmosphere which would lead to better understanding of the physical basis of climate. During the year, studies were initiated to identify climatic regions and boundaries around the Northern Hemisphere by means of plant species and other biological indicators. Changes in the climate, past and present are most pronounced and most easily detected in the vicinity of climatic boundaries. Evidence of climatic change over periods of time can



The GARP Atlantic Tropical Experiment covers almost 40 percent of the global equatorial belt. Observations of weather conditions will be obtained from a variety of observational platforms, including land stations, ships, aircraft, and satellites. In the B-scale area of the Eastern Atlantic Ocean (a polygon indicated by a dashed line), very detailed analyses will be obtained by a concentration of ships and aircraft.

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* Although administered by the Research Directorate, GARP is included here because of its identification as one of the Foundation's National and Special Research Programs.

usually be interpreted in terms of movement of climatic boundaries.

GARP is associated with the following field experiments that have taken place, are occurring, or being planned throughout the world. The countries listed in parentheses indicate those that initiated the experiment.

MONSOONEX—Monsoon Experiment (India)
AMTEX — Air-Mass Transformation Experiment (Japan)
POLEX — Polar Experiment (U.S.S.R.)
NORPAX — North Pacific Experiment (U.S.A.)
LIE — Line Island Experiment (U.S.A.)
TROMEX — Tropical Meteorology Experiment (International)
FGGE — First GARP Global Experiment (International)
AIDJEX — Arctic Ice Dynamics Experiment (U.S.A./Canada)
WAMFLEX — Wave Momentum Flux Experiment (U.S.A.)
BDSP — Basic Data Set Project (International)
VIMHEX — Venezuela International Meteorological and Hydrological Experiment (U.S.A.)

IFYGL — International Field Year of the Great Lakes (U.S.A./Canada)
BOMEX — Barbados Oceanographic and Meteorological Experiment (U.S.A.)
ATEX — Atlantic Tropical Experiment (International)
JASIN — Joint Air Sea Interaction (United Kingdom)
GATE — GARP Atlantic Tropical Experiment (International)
CAP — Continental African Project (U.S.A.)
JONSWAP II — North Sea Air Sea Interaction Experiment (Germany)
ASCENA — Niger River Project (Africa)
CAENEX — Complex Atmospheric Energetics Experiment (U.S.S.R.)

INTERNATIONAL DECADE OF OCEAN EXPLORATION

The Office for the International Decade of Ocean Exploration (IDOE) entered its second year with programs continuing in environmental quality, environmental forecasting, and seabed assessment. The programs were expanded during the year, and a fourth program — living resources — was added.

Concern for the environment is a major consideration in IDOE, and the staff has worked closely with the oceanographic community to develop research programs leading to the assessment of the quality of the marine environment, the potential utilization of marine resources, and the prediction of the state of the world's oceans and their impact on global weather. In particular, the Baseline Data Acquisition Project completed studies on concentrations and distribution of chlorinated hydrocarbons, petroleum hydrocarbons, and heavy metals in the Atlantic and Pacific Oceans, the Gulf of Mexico, and the Caribbean Sea. Significant results included the detection of polychlorinated biphenyls in most marine animals studied and petroleum hydrocarbons in open ocean biological communities. The resulting data were evaluated at an international conference in May 1972, and the conference report was made available to the U.N. Conference on the Human Environment. During the evaluation conference, research priorities on studies of the effects of pollutants were recommended. They are now being used as a guide to subsequent IDOE program development.

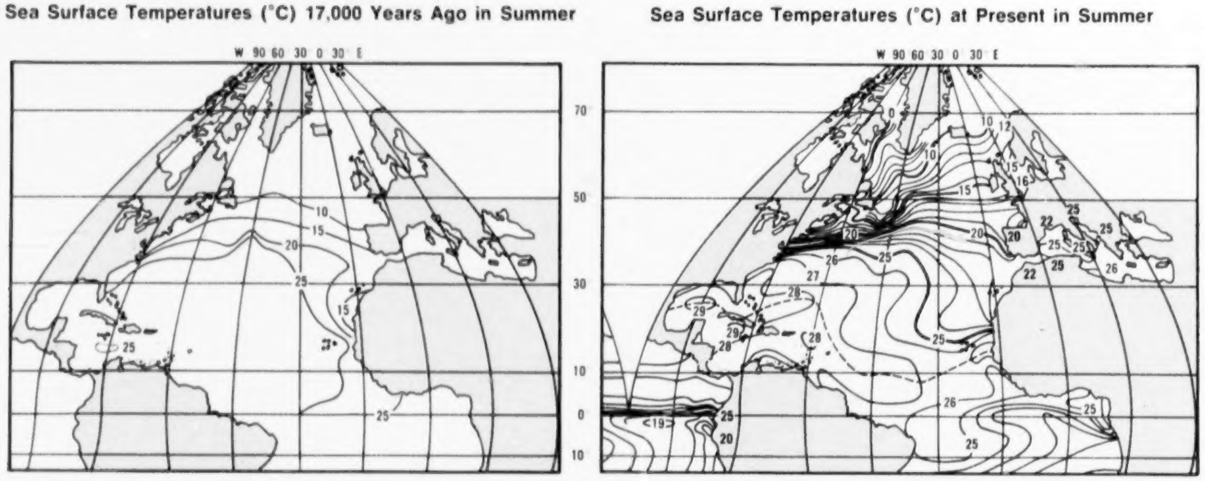
A Pollutant Transfer Processes Project was designed to determine the pathways of pollutants to and within the ocean and the factors affecting pollutant transfer within those pathways. Knowledge in these critical areas will be essential for subsequent studies on effects and fates of pollutants.

Preparations were completed for the Geochemical Ocean Sections Study (GEOSECS), a program of measuring oceanic constituents at all depths along sections from the Arctic to the Antarctic in the Atlantic and Pacific Oceans. The first major cruise began in July 1972. Trace constituent and radioisotopic data are being used to establish geochemical baselines and for quantitative studies of oceanic mixing and descriptive models of ocean circulation. These studies and models are important for research in marine environmental quality and environmental forecasting.

The Environmental Forecasting Program consists of the Mid-Ocean Dynamics Experiment (MODE), a study of the nature and role of medium-sized eddies in ocean circulation; the North Pacific Experiment (NORPAX), a long-term study of large-scale ocean-atmosphere interaction in the North Pacific; and the Climate: Long-Range Investigation, Mapping and Prediction (CLIMAP) program, a study of changes in current patterns and water mass properties during the Quaternary period. Research results of the programs will provide a basis for improved and extended weather forecasts and lead to a better understanding of climate and ocean circulation. Important environmental forecasting studies also are under way in the Living Resources Program (physical aspects of coastal upwelling) and in the Environmental Quality Program (water mass circulation in the deep ocean).

MODE, begun in 1971, involves 12 U.S. and three foreign institutions in a complex program of theory, numerical modeling, and field experiments. Preliminary field work and instrument development are being carried out simultaneously. The first full experiment starts in March 1973.

The NORPAX staff will spend several years examining historical data, developing a numerical model, constructing buoy network hardware, and doing preliminary field work. By 1976, NORPAX will be using 18 telemetering buoys across the north Pacific Ocean.


Sea Surface Temperatures (°C) 17,000 Years Ago in Summer
Sea Surface Temperatures (°C) at Present in Summer
W 90 60 30 0 30 E
70
50
30
10
0
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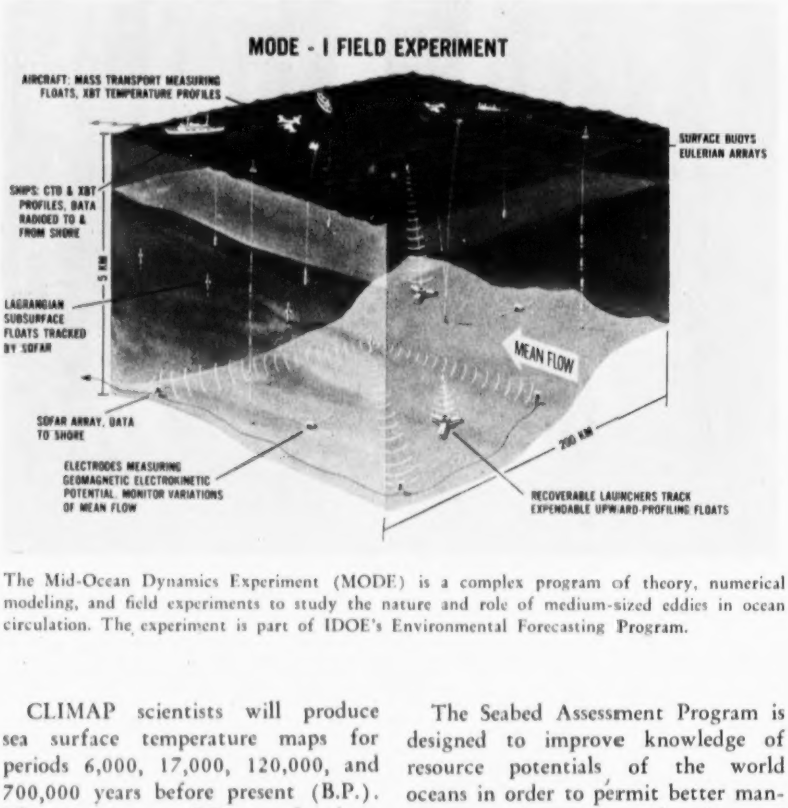
CLIMAP scientists are constructing maps that will indicate sea surface temperatures for different periods thousands of years ago. The map to the left shows surface temperatures (°C) 17,000 years ago during the summer in the Atlantic Ocean. The map to the right shows present-day temperatures during the summer for the same area.


MODE - I FIELD EXPERIMENT
AIRCRAFT: MASS TRANSPORT MEASURING FLOATS, XBT TEMPERATURE PROFILES
SURFACE BUOYS EULERIAN ARRAYS
SHIPS: CTD & XBT PROFILES, DATA RADIOED TO & FROM SHORE
5 KM
LAGRANGIAN SUBSURFACE FLOATS TRACKED BY SOFAR
MEAN FLOW
SOFAR ARRAY, DATA TO SHORE
ELECTRODES MEASURING GEOMAGNETIC ELECTROKINETIC POTENTIAL, MONITOR VARIATIONS OF MEAN FLOW
200 KM
RECOVERABLE LAUNCHERS TRACK EXPENDABLE UPWARD-PROFILING FLOATS

The Mid-Ocean Dynamics Experiment (MODE) is a complex program of theory, numerical modeling, and field experiments to study the nature and role of medium-sized eddies in ocean circulation. The experiment is part of IDOE's Environmental Forecasting Program.

CLIMAP scientists will produce sea surface temperature maps for periods 6,000, 17,000, 120,000, and 700,000 years before present (B.P.). The 17,000 years B.P. map has been completed.

The Seabed Assessment Program is designed to improve knowledge of resource potentials of the world oceans in order to permit better management of marine exploration and exploitation and to assist industry in planning more detailed investigations. The program includes geological and geophysical investigations of continental margins, ocean mineral deposits, and mid-oceanic ridges. The Eastern Atlantic Continental Margins Study, now 50 percent complete, may outline potentially valuable oil provinces and mineral accumulations. Mid-Atlantic Ridge studies have been the subject of workshops in the United States and abroad. A cooperative program on the mechanisms of seafloor spreading and on the generation of heavy metal deposits along the ridge crest has been proposed.

When an IDOE workshop on deep ocean manganese deposits disclosed the existence of considerable unanalyzed data in oceanographic institutions, IDOE supported an analysis to report on deficiencies, state of the art, and priorities in the study of such deposits.

In the Living Resources Program, experimental verification of physical oceanographic hypotheses and coastal upwelling numerical models took place in mid-1972. The experiment was the first step in a comprehensive Coastal Upwelling Ecosystem Analysis Program designed to combine the physical oceanographic and numerical modeling capabilities with existing biological oceanographic and ecosystems modeling techniques.

The National Oceanic and Atmospheric Administration's (NOAA) Environmental Data Service (EDS) provides centers for correlation and storage of data from IDOE programs. EDS staff and IDOE investigators agree on format and schedules for data transmission to the centers, and the data flow from ongoing projects has already started.

Instrumentation devices developed under IDOE projects were tested and calibrated by NOAA's National Oceanographic Instrumentation Center. In addition, laser Raman spectroscopy is being evaluated for oceanographic analyses.

The United States formally presented its IDOE program to the Intergovernmental Oceanographic Commission (IOC) in October 1971. The commission endorsed the program and called on member nations to present their programs to the IOC Executive Council. By the end of fiscal year 1972, the contributions of about 30 foreign countries — in the form of ships, laboratories, and personnel — to NSF-initiated programs exceeded $3 million, and there was promise of even greater participation.

In fiscal year 1972, $20 million in program funds were distributed in the following proportions: environmental forecasting, 45 percent; environmental quality and seabed assessment, 25 percent each; general support and living resources, 5 percent. Other government agencies continued to play an important role in the IDOE program. Within the four programs, almost 15 percent of the funds went to Federal laboratories; the remainder went to academic institutions and industry.

POLAR PROGRAMS

Research in the Arctic supported through the Office of Polar Programs centered on two large projects. A pilot study for the Arctic Ice Dynamics Joint Experiment was carried out in March and April 1972, when 80 university and government scientists from the United States, Canada, and Japan occupied three manned stations in the Arctic Ocean pack ice northeast of Barrow, Alaska. Five unmanned buoys provide supplemental data. The objective of the experiment is to improve techniques of forecasting ice conditions and to determine the influence of sea ice on the heat exchange between ocean and atmosphere. The University of Washington is coordinating the project, which is funded by NSF as well as other United States and Canadian agencies.

The Tundra Biome project continued in the Arctic with scientists from 40 institutions. Two successful years of research have been completed at Point Barrow, Prudhoe Bay, and Eagle Summit, Alaska, and comparative studies of alpine tundra are being made at Niwot Ridge, Colo. About 200 investigators have been involved in interrelated field research and extensive computer modeling on terrestrial and aquatic ecosystems. The goal is to develop models that can be used to predict the effects of natural and artificial changes on the tundra ecosystems.

Beginning with fiscal year 1972, the Foundation assumed responsibility for funding the entire U.S. program in Antarctica except for icebreaker support. Under an interagency agreement, the U.S. Navy continues to provide the major portion of logistic support for the program. The loss to the program of two of the five ski-equipped aircraft used in Antarctica is putting a heavy strain on the logistics operations, and two of the remaining aircraft must be retired soon. Despite these handicaps, research in many disciplines continued year-round at four stations. In the austral summer, 142 investigators carried out 51 research projects at U.S. stations and in the field. Other investigators were aboard the research ships *Eltanin* and *Hero* and on two icebreakers. As in past years, the U.S. Navy and the U.S. Coast Guard supported the program logistically.

Byrd Station, an under-snow installation in Marie Byrd Land that had been occupied continuously since its

The icebreaker *Southwind* anchored near Palmer Station on the Antarctic peninsula shortly before researchers began the survey of seals inhabiting the pack ice of the Bellingshausen and Amundsen Seas. (Photo by U.S. Navy) completion in 1962, was closed in January 1972. Siple Station in Ellsworth Land, which is strategically located for studies of the upper atmosphere, will become a year-round station next year.

Working from the icebreaker *Southwind*, researchers from the University of Idaho and the University of Minnesota took a census of seals and other animals inhabiting the pack ice of the Bellingshausen and Amundsen Seas, an area of about 140,000 square kilometers. Early analysis indicates that nearly a million seals inhabit the area. This and similar information from other areas of the southern ocean contribute to policy-making in the field of conservation, as exemplified by the Conference for the Conservation of Antarctic Seals, held in London in February 1972.

Field work was carried out to select the best sites for two drilling projects to begin next summer — one in the sea and the other on land. *Eltanin* cruised the Ross Sea to obtain essential preliminary information for the deep sea drilling ship *Glomar Challenger*, which will begin the first of three seasons of Antarctic drilling in January 1973. Seismic and magnetic properties of the ice-free valleys of southern Victoria Land were measured in preparation for a drilling project to be carried out jointly by Japan, New Zealand, and the United States.

OCEANOGRAPHIC FACILITIES AND SUPPORT

Ocean sciences research is supported in three of the directorate's offices, with different objectives, while general support for the academic oceanographic fleet is provided through the Office for Oceanographic Facilities and Support (OFS). In fiscal year 1972, OFS functions were expanded to include: (1) operations support for facilities (other than ships), technician pools, data processing groups, and University National Oceanographic Laboratory System (UNOLS) staff activities; and (2) acquisitions support for ship construction, shared shipboard and shore laboratory equipment, and ship staging facilities. Support provided through OFS was approximately doubled to include these expanded services.

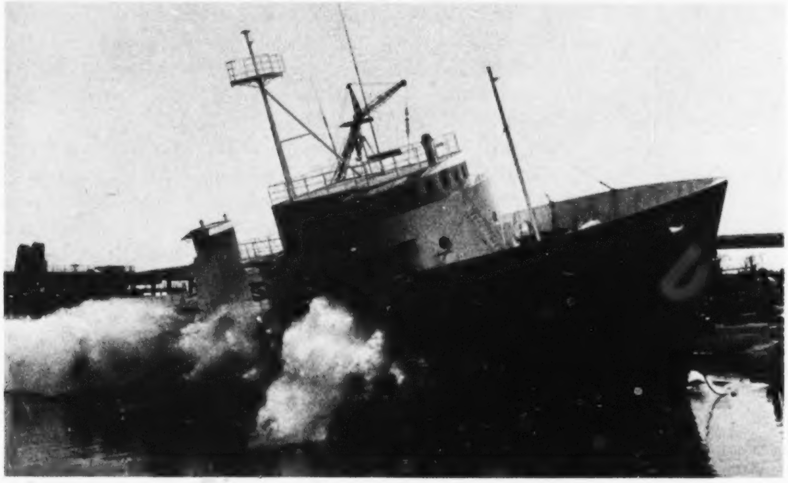
The increased activity under OFS primarily results from efforts to develop a broadly based management approach to the acquisition, operation, and use of large research facilities for the academic oceanographic community. The cooperative association of institutions, UNOLS, was chartered by 18 federally funded ship operator institutions in September 1971 to bring about better methods of sharing oceanographic facilities. This coordination structure involves the two principal supporting agencies — NSF and the Navy — and other interested agencies. OFS undertook the responsibility for planning, coordinating, and managing the Foundation's share of support for the UNOLS staff office and serves in a liaison capacity with the community organization.

An advisory council representing the entire academic oceanographic community provides an overview of all UNOLS activities. Through the advisory council, UNOLS monitors and evaluates how effectively the facilities are used, assesses the current and future needs for adding or phasing out facilities, and provides reports and recommendations to the Federal funding agencies.

During the year, a contract was made with Woods Hole Oceanographic Institution to construct a ship approximately 170 feet long. Another NSF-funded ship, R/V *Columbus Iselin*, was launched in March and will be operated by the University of Miami under UNOLS agreements.

Other awards included 21 grants for about $1.5 million for updating and improving oceanographic materials such as shipboard scientific equipment and facilities and specialized instrumentation for data processing, communications, and navigation.

These crabeater seals are the most numerous species in the antarctic waters. (Photo by U.S. Navy)



The research vessel *Columbus Iselin* splashes into the sea March 1, 1972, at the University of Miami Rosenstiel School of Marine and Atmospheric Science.

OCEAN SEDIMENT CORING PROGRAM

The Ocean Sediment Coring Program is an exceptionally important effort to further our understanding of the world in which we live. It comes at a time when technology is available to do the monumental task of drilling beneath the floor of the deep ocean basins, when geological sciences have just achieved a unifying and global perspective of the history of the earth, and when social and economic interest in the oceanic realms is greater than ever.

The Deep Sea Drilling Project, which at present constitutes the Ocean Sediment Coring Program, has been in operation since August 1968. Its objective is to explore the age, history, and development of the ocean basins and their marginal seas by means of drilling and coring the ocean floor. Operations are conducted from the specially designed drilling ship *Glomar Challenger*, owned and operated by Global Marine, Inc., of Los Angeles under a subcontract to the University of California. Scripps Institution of Oceanography at La Jolla is responsible for management of the project.

This sonar positioning beacon being inspected aboard D/V *Glomar Challenger* during Leg 19 in the Bering Sea is used as a reference on the ocean bottom in the system that keeps the vessel over a drilling and coring site. (Photo by Scripps Institution of Oceanography)

The project's activities for the past 4 years of deep ocean drilling and coring (August 1968 to August 1972) were designed for 25 cruises or legs, each of which lasts approximately 2 months. During the first 23 legs, which ended in May 1972, 349 holes had been drilled at 250 locations in the Atlantic, Pacific, and Indian Oceans, and in marginal seas. Approximately 66,000 feet of core have been recovered. The maximum penetration into the bottom sediment achieved so far is 4,265 feet; maximum water depth in which drilling has been accomplished is 20,483 feet.

The typical scientific staff on board the drilling ship consists of 10 or 11 specialists in sedimentology, paleontology, and marine geophysics. Particular subjects — such as geochemistry — may be emphasized on certain legs and require stronger representation in that field.

Foreign scientists contribute substantially to work conducted aboard *Glomar Challenger*. To date, 66 scientists from 17 foreign countries have participated. National and international scientific guidance to Scripps is coordinated through the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). This consortium, consisting of five major U.S. oceanographic institutions, advises on drilling itineraries, site selection, initial core descriptions, and other aspects of the operation.

Initial descriptions of the cores and interpretations of scientific results from each leg undertaken by *Glomar Challenger* are published in a series of reports called *Initial Reports of the Deep Sea Drilling Project*. Each volume gives a description of the cores and an overall scientific synthesis of the cruise.

During the past year, the Foundation extended its contract with the University of California to cover 3 additional years of drilling and coring activities. Thus, the services of *Glomar Challenger* are now contracted for until August 1975.

Two major departures from prior work are planned for the extended project. Drilling in seas surrounding Antarctica will be done during three austral summers, and attempts will be made to increase gradually the capability to drill and take cores of the hard igneous rock below the sedimentary layer. A computer-based data retrieval system is being developed to aid scientists in selecting samples.

Recent cruises of *Glomar Challenger* have traversed the northeastern Pacific Ocean, Bering Sea, the western Pacific Ocean including the Melanesia area, the Indian Ocean, and the Red Sea. Data obtained from these cruises will assist in determining the magnitude and direction of both horizontal and vertical crustal motion. There are indications, for instance, that the Pacific sea floor has moved horizontally across the Equator in a northerly direction. In addition, a widespread hiatus in the sedimentary record has been found that is particularly evident in the Australia-New Zealand region. This gap in the record suggests that a "circum-polar" ocean current flowed north of Australia until Oligocene time when Australia had drifted far enough away from Antarctica to transfer the current to its present course.

Indications of vertical motion come from the Ninetyeast Ridge in the Indian Ocean, now about a mile below sea level. It was found to have been above sea level at one time and to contain coal, lagoonal deposits, and oyster beds.

NATIONAL RESEARCH CENTERS

The National Research Centers have the equipment, the facilities, and the expertise to support large-scale and complex investigations that could not have been undertaken by individual universities. They represent large investments in capital equipment and operating costs. Furthermore, each major discovery or the attainment of the threshold of a new breakthrough increases the demand for larger, better, and more sophisticated equipment. In astronomy, for example, the progress in recent years has been spectacular. Each increment in observational capability, in the form of more powerful instruments and improved observational techniques, brings us one step closer to understanding two of the great mysteries of mankind — the origin and eventual fate of the universe.

NATIONAL ASTRONOMY AND IONOSPHERE CENTER

The National Astronomy and Ionosphere Center (NAIC), operated under contract with the Foundation by Cornell University, has its headquarters on the Cornell campus, Ithaca, N.Y. The observing facilities are located in Puerto Rico at a site 12 miles south of Arecibo. The principal observing instrument is a spherical antenna, 1,000 feet in diameter, that can function either actively as a radar telescope or passively as a radio telescope.

During fiscal year 1972, steps were taken to upgrade the reflector by installing a highly precise surface that

Table 5
National Research Centers
Fiscal Years 1970, 1971, and 1972

	Fiscal year 1970			Fiscal year 1971			Fiscal year 1972		
	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total
National Astronomy and Ionosphere Center	$ 150,000	$ 1,400,000	$ 1,550,000	$ 3,755,000	$ 2,343,600	$ 6,098,600	$ 1,900,000	$ 2,787,500	$ 4,687,500
Kitt Peak National Observatory	46,000	6,379,000	6,425,000	127,000	7,072,600	7,199,600	456,000	7,243,881	7,699,881
Cerro Tololo Inter-American Observatory	365,000	1,535,000	1,900,000	313,000	1,967,000	2,280,000	385,000	2,115,000	2,500,000
National Radio Astronomy Observatory	675,000	5,125,000	5,800,000	- 0 -	6,837,400	6,837,400	80,000	6,589,900	6,669,900
National Center for Atmospheric Research	117,840	11,323,960	11,441,800	270,990	14,224,614	14,495,604	1,000,000	17,177,416	18,177,416
Total	$ 1,353,840	$25,762,960	$27,116,800	$ 4,465,990	$32,445,214	$36,911,204	$ 3,821,000	$35,913,697	$39,734,697

will allow research to be conducted at wavelengths shorter than the present limit of about 50 centimeters. Completion of the resurfacing program is scheduled for May 1974. It will proceed in stages that will allow the observatory to maintain its research capabilities and observational programs.

Another major Arecibo program initiated during the year was the design and development of an S-band radar transmitter. This project is being supported by the National Aeronautics and Space Administration. When this new transmitter is installed in early 1974, it will be possible to map the surfaces of planets at wavelengths in the 10-centimeter range. Radar astronomers will be able to study the details of the cloud-covered surface of Venus with a resolution of 2 to 5 kilometers, equaling the quality of the best earth-based optical photographs of the moon. In addition, the planet Mercury will be subject to mapping by radar techniques. Investigations of the moons of Jupiter can be conducted and, using these moons, the atmosphere and ionosphere of the planet Jupiter itself can be studied.

During the past year, a new high-powered, 430-MHz line feed was placed in operation to permit more detailed and accurate observations to be made of nearby planets, extended radio sources, and the Earth's ionosphere.

There were 31 visitors from 16 institutions using the Arecibo telescope in fiscal year 1972. The goal of NAIC is to apportion 70 percent of all observing time to visiting scientists, with the remainder being used for staff observations and calibration and maintenance. Upon completion of the resurfacing and the S-band radar, it is expected that visitor use of observatory facilities will increase. NAIC employs 105 scientific, technical, maintenance, and administrative personnel.

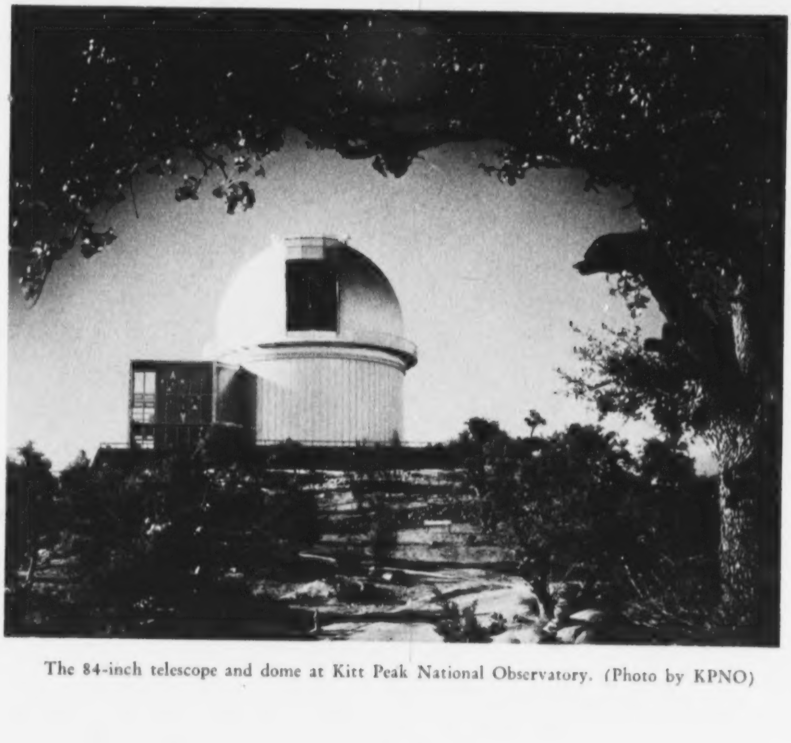
KITT PEAK NATIONAL OBSERVATORY

The Kitt Peak National Observatory (KPNO) is operated under a National Science Foundation contract with the Association of Universities for Research in Astronomy. The observatory supports visitor-oriented observational and theoretical research programs in stellar, solar, and planetary astronomy, and engages in programs to develop and improve astronomical research facilities and auxiliary instrumentation. The observing facilities are on Kitt Peak, a 6,000-foot-high mountain located 40 miles west of Tucson, Ariz. The observatory headquarters at Tucson, adjacent to the campus of the University of Arizona, provide office, research, and engineering facilities for the 325-member staff and visitors.

Six stellar telescopes of 84-inch, 50-inch, (two) 36-inch, and (two) 16-inch apertures were operated in fiscal year 1972 in support of 102 visiting astronomers and 44 graduate students from 55 U.S. institutions and five foreign countries. Visitor scheduling of observing time on the stellar telescopes totaled 61 percent of the total available time. The two largest telescopes were assigned to visitors 70 percent of the time.

The McMath solar telescope was used by 38 visiting scientists and 12 graduate students. Of these, 45 came from 22 U.S. institutions and five from foreign countries.

In fiscal year 1972, the mounting for the new 150-inch telescope was installed within the new observatory building and dome. Observatory personnel are conducting alignment tests in preparation for installation of the telescope optics in the late summer of 1972. The 150-inch fused quartz mirror has been completed and tests indicate that the performance characteristics of the mirror surface are excellent. Fabrication of auxiliary instrumentation for this telescope is under way. Also, a 36-inch mirror was in-



The 84-inch telescope and dome at Kitt Peak National Observatory. (Photo by KPNO) stalled and a drive system completed to feed light into the laboratory at the Coudé focus of the 84-inch telescope.

Public visitors to Kitt Peak during the year numbered more than 48,500, with representation from all 50 States and five foreign countries.

CERRO TOLOLO INTER-AMERICAN OBSERVATORY

The Cerro Tololo Inter-American Observatory (CTIO) is operated under contract with the Foundation by the Association of Universities for Research in Astronomy. The observing facilities at Cerro Tololo, atop a 7,200-foot-high mountain in the foothills of the Chilean Andes, include several major telescopes: 60-inch, 36-inch, 24-inch, and (two) 16-inch reflectors, and a 24-inch Schmidt-type instrument. The headquarters, located at La Serena, contain offices, laboratories, library, engineering support facilities, and a computer for the use of CTIO staff and visiting astronomers.

The observatory provides U.S. astronomers with excellent facilities with which to observe objects in the southern skies. Many significant celestial objects, including nearby star clusters, the southern Milky Way, and the two Magellanic Clouds can be viewed only from the Southern Hemisphere.

During fiscal year 1972, 75 astronomers from 36 institutions made observations at CTIO. Visitors from the United States, including graduate students, were assigned 58 percent of the available telescope time. Another 21 percent of the telescope time was divided among foreign visiting observers. The remaining 21 percent was used by staff members of CTIO and the Kitt Peak National Observatory (KPNO) for research and maintenance activities.

During the year, several new pieces of observing instrumentation were brought into use. The photoelectric scanner, built at the Harvard College Observatory under the supervision of John Danziger, is now being used by CTIO staff and visitors. A faint star photometer, developed and built according to specifications of Merle Walker of the University of California, promises to be especially valuable for observations of the Magellanic Clouds. And working in cooperation with Kent Ward of the Carnegie Institution of Washington, D.C., CTIO staff adapted a sophisticated electronic imaging tube for use with the Cassegrain spectrograph.

The building and dome for the 150-inch telescope are essentially complete and ready for the installation of the mounting early in calendar year 1973. The grinding, polishing, and figuring of the Cervit mirror blank for the instrument began at the KPNO optical shops in Tucson in December 1971. It is expected that the mirror will be completed late in calendar year 1973 and shipped to CTIO shortly thereafter.

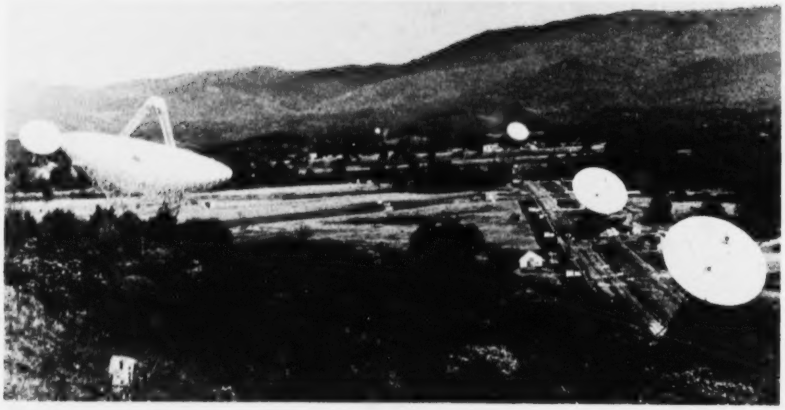
An aerial view of the Cerro Tololo Inter-American Observatory, with the essentially complete building and dome that will house the 150-inch reflector, perhaps early in 1974. (Photo by CTIO)

NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory (NRAO), with headquarters in Charlottesville, Va., is operated and managed by Associated Universities, Inc., under contract to the Foundation. The principal observing site is at Greenbank, W. Va.; a second observing facility is at the site of Kitt Peak National Observatory in Arizona. The observatory provides the U.S. scientific community with large ground-based radio telescopes, sophisticated auxiliary instrumentation, and the necessary support facilities for research in radio astronomy.

The major observing instruments at Greenbank are a 300-foot-diameter telescope constrained to move in a meridian plane, a 140-foot-diameter fully steerable parabolic telescope, an interferometer array incorporating three 85-foot-diameter dishes, and a portable 42-foot-diameter antenna used for remote operations with the interferometer. A 36-foot-diameter millimeter-wave telescope is located at Kitt Peak.

Two new receivers have been added to the 31 receivers now available at NRAO, one for use with the 140-foot and 300-foot telescopes, the other with the 36-foot telescope. A new 50-channel filter-bank receiver has been added to the 140- and



The three major telescope systems at the Greenbank, W.Va., site of the National Radio Astronomy Observatory are an interferometer array of three 85-foot-diameter telescopes, a newly surfaced 300-foot telescope that moves in a meridian plane (left, front), and a fully steerable 140-foot telescope (rear). (Photo by NRAO)

300-foot telescopes to facilitate the acquisition, processing, and analysis of observational data.

The observatory has also completed development of a laser range-measuring device for use in surveying the surfaces of large paraboloidal antennas. This instrument can measure distances up to 60 meters with an accuracy of 1/10,000 of a meter in a measuring time of 2.5 seconds.

Sensitive Very Long Baseline (VLB) interferometer systems were put into operation to study the compact-point and point-like radio sources found in galaxies and quasars. Presently, 13 separate recording systems are based at various sites throughout the United States and Europe. Comparison of recordings made simultaneously at two or more sites allows radio astronomers to construct high angular resolution images of the radio sources. The highest resolution obtained so far has been achieved in a series of cooperative experiments between NRAO staff, astronomers in the Soviet Union, and scientists using the 210-foot NASA space tracking antenna at Goldstone, Calif. Further experiments yielding even greater resolutions are planned. Sensitive maser receivers, which Soviet astronomers are building specifically for this work, will be used by the U.S. and U.S.S.R. scientists.

During fiscal year 1972, 168 visitors from 43 U.S. and foreign research organizations were allocated an average of 63 percent of the available telescope time on NRAO instruments.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Reliable long-term weather forecasts are of vital importance to some of our basic industries such as agriculture and shipping. The National Center for Atmospheric Research (NCAR) plays an important role in atmospheric research programs that are often worldwide in scope. Its nonpareil array of instrumentation and logistics equipment makes this center well suited to undertake large-scale projects on behalf of, and with the participation of, the academic community.

NCAR is operated under NSF sponsorship by the University Corporation for Atmospheric Research. NCAR's permanent installations include the Mesa Laboratory, its headquarters and principal laboratory in Boulder, Colo.; the National Scientific Balloon Facility at Palestine, Tex.; the Research Aviation Facility at Jefferson County Airport near Boulder; and the Field Observing Facility's radar and instrument test site at Marshall, Colo.

During fiscal year 1972, a major fraction of NCAR's research effort was devoted to cooperative research involving about 120 visiting university scientists. Some of these projects, characterized by work toward particular goals on specific schedules over a lengthy period of time, have been designated "key projects." NCAR's current key projects are:

- The National Hail Research Experiment (NHRE), a 5-year field program with two objectives: to gain an increased understanding of all aspects of the cloud physics and microphysics of severe convective storms that produce hail and, if possible, to develop a practical method for suppressing the occurrence of damaging hail. The NHRE field research area is in northeastern Colorado in a region of very high hailstorm frequency. Several Government agencies, as well as six universities, participate in this program.

- The Global Atmospheric Research Program (GARP), an international effort designed to increase the accuracy of weather forecasting over periods from 1 day to several weeks and to gain a better understanding of the physical basis of climate. NCAR has been assigned the lead role in the Observing System Simulation Experiment. In addition, the center will provide an aircraft with accurate motion-sensing instrumention for use in the 1974 GARP Atlantic Tropical Experiment and subsequent field experiments. A Lockheed Electra has been leased and is now being

An 8½-meter-diameter antenna for a dual-wavelength analytical radar is lowered into place on its pedestal at the field headquarters of the National Hail Research Experiment at Grover, Colo. (Photo by NCAR)

modified for installation of the research instrumentation.

- The Fate of Atmospheric Pollutants Study (FAPS), part of a study of air pollution in the St. Louis area involving a number of Federal agencies, university groups, and other organizations. The objectives of FAPS are closely linked to the practical problems of the effects of urban air pollution on regional and global air quality and its possible effects on weather and climate.

COMPUTING ACTIVITIES IN EDUCATION AND RESEARCH

The United States continues to maintain a leading position in computer science and technology as exemplified by the favorable balance of trade in computers — approximately $1 billion a year. In its program of Computing Activities in Education and Research, the Foundation continues to pursue the objective of providing the nation with a base of computer science knowledge that will foster innovative approaches for the use of computers in education and research. Progress in this program should also allow Government, industry, academic institutions, and other users to evaluate better the capabilities and limitations of computers, as well as to develop methods of using computer technology to its fullest potential.

COMPUTER SCIENCE AND ENGINEERING

A multiprogrammed computer can provide service to hundreds of users at the same time. Such a system contains a large number of programs, most of which are independent of each other and some of which may be required by several of the users. It consists of a variety of components such as memories, printers, tape drives, document readers, processors, etc., each of which operates at differing rates and each of which can operate independently of the others to a large extent. Thus, at one instant in time, the system may be printing a report for one user, receiving data by telephone from a second user, searching a tape file for a third user, doing arithmetic for a fourth user, and performing still other functions for other users. The question of how to construct, organize, and program the "operating system" which controls all of this activity so that the users all receive satisfactory, economical service continues to provide interesting and difficult problems in computer science research.

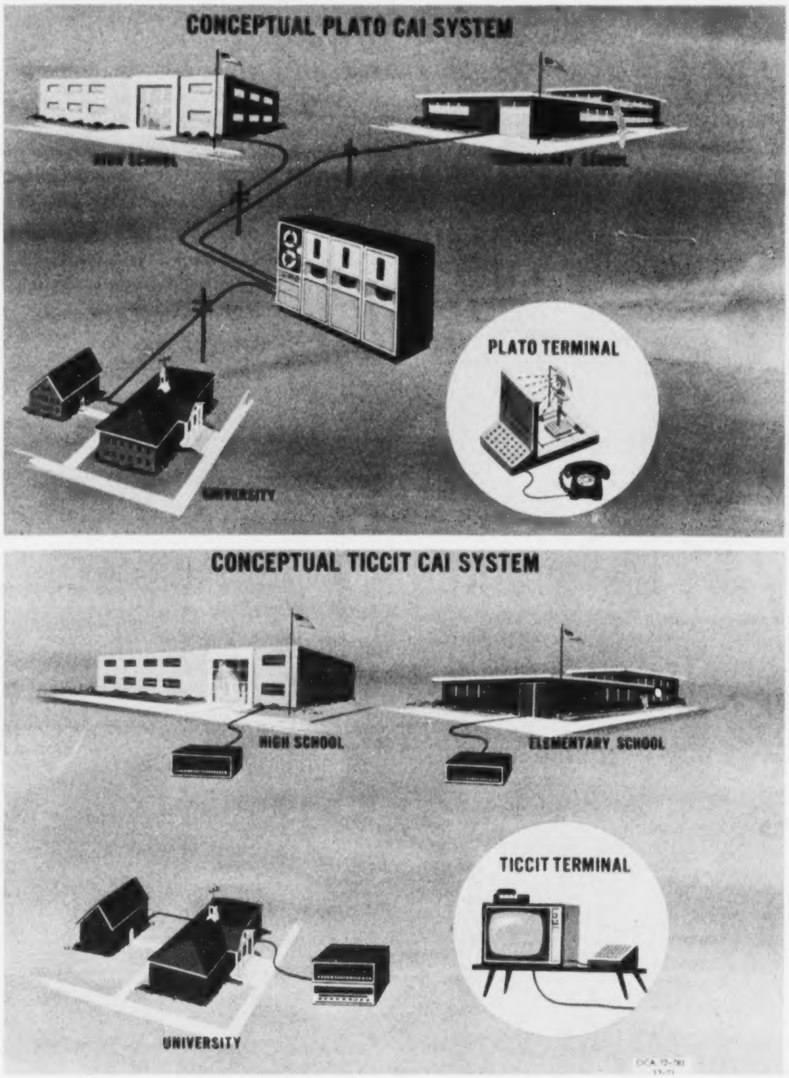
The theoretical study of multiprogrammed systems is generally based on an abstract model of the system as an interconnected network of queues, each queue corresponding to programs waiting to receive service from one of the components. As a program receives the needed service, it is removed from its former queue and attached to the queue for the component providing the next service needed by that program. To construct a specific network model for each proposed system is expensive, difficult, and poses problems of detail we do not know how to solve. Recently, K. M. Chandy of the University of Texas at Austin has taken the first steps to develop a more general theory in which analytical solutions can be obtained for large classes of queueing networks. Such a theory would make it possible to optimize the performance of a multi-programmed system through the choice of components and their organization and the type of queueing discipline used by the operating system.

At Iowa State University, R. M. Stewart is studying the performance of an unconventional computer (called SYMBOL) specially designed to facilitate experimentation with operating systems, while the measurement and performance evaluation of more conventional operating systems is being investigated by G. Estrin at the University of California, Los Angeles, and by J. Noe at the University of Washington.

COMPUTER INNOVATION IN EDUCATION

The U.S. system of education is placing increasing demands on the nation's resources. The fraction of the GNP devoted to all educational expenditures (public and private, from kindergarten through graduate school) has risen steadily since the end of World War II — from about 3 percent to over 7 percent in 1969-70. The Computer Innovation in Education Program has as its goal improvement in the cost-effectiveness of education generally (with special emphasis on science education) through the application of modern computer and communication technology. In fiscal year 1972, approximately $8.4 million was awarded toward this end to academic and nonprofit organizations.

Based on developments supported by earlier Foundation awards, contracts were negotiated with the University of Illinois, the MITRE Corp., and Educational Testing Service for a 5-year test and evaluation of the educational, engineering, and economic feasibility of two alternate systems of computer-assisted instruction, applied principally to instruction at the community college level. Illinois' PLATO (Programmed Logic for Automatic Teaching Operations) system and MITRE's TICCIT (Time-Shared Interactive Computer Controlled Information Television) system are shown schematically.



The concepts of two computer-assisted instruction systems developed with the Foundation's support are shown above. The PLATO CAI system utilizes a central computer which transmits its information via television and telephone cables to the various terminals. The TICCIT system employs separate minicomputer units containing their own educational packages and designed to transmit to special television terminals.

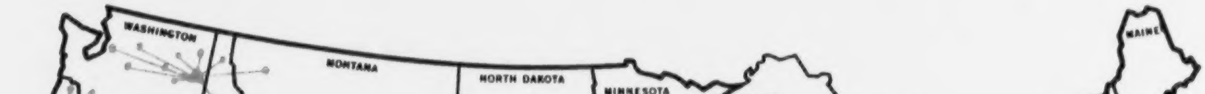
Widespread application of computer-based instructional systems depends in part upon the development of suitable instructional strategies and innovative computer-oriented curricular materials — at all levels of education. In fiscal year 1972, 21 grants were awarded for this purpose.

In higher education, researchers at Purdue University, the University of Oregon, and the University of Nebraska are working together to develop and test curricular materials for computer-based experiments in an analytical chemistry laboratory. At the University of Iowa, computer-based curricula are being developed for economics, political science, and sociology. Innovative materials are being developed at the University of California, Irvine, for teaching physics, using an interactive computer graphics system to present complex processes and phenomena in situations where conceptualization is difficult. At the University of Pittsburgh, Thomas Dwyer is testing the use of a commercial, time-shared terminal, and is developing a wide variety of curriculum modules in physics, biology, the social sciences, mathematics, and computer science for use in secondary schools.

Seymour Papert of the Massachusetts Institute of Technology and Robert Davis of Syracuse University are both using computers to teach problem-solving in mathematics to elementary school children. The children are taught to write computer programs which control a device called a "turtle." With this computer device, children have demonstrated their ability to write programs to draw simple figures, construct complex geometric designs, generate music and poetry, and solve motion problems in physics.

Over the past 4 years, the National Science Foundation has assisted in the establishment of educational computer networks, through the Regional Cooperative Computing Activities Program, to explore the application of computer techniques and networks to the educational process. Specifically, the regional program involved training faculty members at institutions willing to share the cost to enable them to explore ways of using computer service to improve the science education of both science and nonscience majors and to provide remote access to computer services necessary to support this activity. Between fiscal years 1968 and 1971, 22 regional computer networks were established. Five of these were Statewide activities in North Carolina, Georgia, New Jersey, Colorado, and Washington.

In fiscal year 1972, 46 grants were awarded to establish: (1) three regional networks making up Pennsylvania's Regional Instruction System for Education (PRISE); (2) a State-



Nearly 350 institutions are part of regional educational computer networks that NSF has assisted in establish wide network in New York involving the State University of New York at Binghamton and 15 participant colleges; and (3) the Florida Regional Cooperative Computing Network comprising 10 institutions. This program will be phased out in fiscal year 1973 with an analysis of the impact of these cooperative approaches on cost and effectiveness in science education.

The figure shows the approximate location of each network supported to date. Involved are 26 major universities, 237 4-year colleges, 43 junior colleges, and 37 secondary schools.

COMPUTER APPLICATIONS IN RESEARCH

Foundation programs in Computer Applications in Research support a wide range of activities to increase the usefulness of computers in the conduct of research. Some projects focus on research methodology including the creation of new computational techniques and computer-based systems. Others involve research, developmental activities, and special studies to explore the resource-sharing potential of a nationwide computer communication network. Still others are directed toward improving the quality and applicability of computer software for research. The three projects described are representative of these programmatic thrusts.

Scientists in the Natural Resources and Environmental Science Program at Purdue University are collaborating to develop a strong capability in the application of computers to their respective research interests. The project is focused on the development of a well-coordinated computer-based laboratory system which incorporates a hierarchical structure of three levels of computing support. As one example, the research of Daniel L. Shankland, Department of Entomology, concerns the integrity and function of nerve networks. Insect nerves are useful systems for detailed study because, unlike those in vertebrates, they can be removed from the animal and retain their functional integrity. Proper analysis of even such relatively simple networks requires the processing of enormous amounts of data, coupled with experimental manipulation of the network by way of controlled feedback effects. Professor Shankland is developing advanced computer-based techniques for detailed analysis and quantitative description of a nerve network that controls breathing in the cockroach, and that shows a basic similarity to the reflex system that controls comparable movements in mammals.

The feasibility and desirability of a national center devoted to computation in chemical research is being examined by the Division of Chemistry and Chemical Engineering of the National Academy of Sciences-National Research Council. A committee of approximately 30 individuals has been formed to carry out the study. The committee membership includes chemists from diverse areas of research, computer scientists, mathematicians, and representatives from other relevant scientific disciplines. The main tasks of the committee are to identify important chemical problems susceptible to solution at such a laboratory, identify special problems of computer science involved, and explore and characterize the structure and operation of such a facility. The committee is concerned also with the broader questions of the impact of such a laboratory on university computing centers, development of computer networks, computer program exchange, and interfacing of the laboratory with the scientific community.

A major thrust is under way to provide researchers with highly accurate, consistent, well-documented, and extensively tested software. A collaborative prototype effort involving the Argonne National Laboratory, the University of Texas, and Stanford University, in cooperation with various field test sites, is under way to certify and disseminate mathematical software. Selected mathematical software is tested first at the three principal institutions and then at 16 field test sites. The certified products are distributed by the Argonne Code Center. A key aspect of this project is the emergence of a collaborative testing methodology.

SCIENCE INFORMATION ACTIVITIES

Science communications cut across not only all of the Foundation's activities but those of the entire Government, academia, and industry as well. The Office of Science Information Service has become the focal point in the Government for the support and coordination of science information activities which, in the end, will have major impact on the efficiency of research conducted and the application of the research results at all levels of our society.

A major effort was made during the past year to revamp the policies, objectives, and organization of the Office of Science Information Service (OSIS) to meet new challenges and responsibilities. Grants totaling approximately $10 million were made in support of systems and services for more effective science communication. An additional $1 million in equivalent excess foreign currencies supported eight contracts for the translation of scientific literature and related information services.

New responsibilities accrued from the Foundation's acceptance of leadership for the Committee on Scientific and Technical Information (COSATI) of the Federal Council for Science and Technology. This assignment, undertaken at the request of the Office of Science and Technology, requires the coordination of Federal science information activities, and parallels the coordination of such activities in non-Federal, academic, and industrial sectors where OSIS had concentrated its attention in prior years. As a corollary to the COSATI assignment, OSIS undertook to serve as the U.S. focal point in international science information relationships.

Changes in policy brought about a substantial reduction in funding projections and timetables for commitments to ongoing systems and permitted reorientation of OSIS efforts. Under the new policy, the cost of initial planning of new information systems (prior to design and development) and their operational costs once testing is completed, are the responsibility of the proposing organization.

In implementing these policy changes, operating practices concerning system development were also altered — chiefly to emphasize contracts rather than grants as the principal mode of support — and OSIS was reorganized into five program elements that permit sharper management focus upon problem areas needing increased attention.

INFORMATION SYSTEMS

The Foundation's Information Systems Program is concerned with computerized bibliographic systems for organizing, processing, and disseminating scientific literature. Such systems are of two main types: product-oriented and user-oriented. Examples of the first category include the discipline-based systems of the Chemical Abstracts Service (CAS), the American Institute of Physics (AIP), and the American Psychological Association (APA), which produce abstracts and indexes in both published and computer-tape form. The AIP and APA systems reached full operational status in fiscal year 1972. CAS brought its Chemical Register to an operational condition and continued development of other system components on an accelerated schedule calling for completion in fiscal year 1975, 18 months earlier than originally planned.

User-oriented systems, which employ the bibliographic tools produced by the discipline systems to serve individuals or groups at academic and research institutions, include six computerized information centers in varying stages of development at the following universities: Stanford, Georgia, Lehigh, UCLA, Ohio State, and Pittsburgh. The first three are approaching operational status where full cost will be borne by the universities, and the others are on schedule toward that goal.

DATA SYSTEMS

The Data Systems Program focuses attention on quantitative and factual data in all fields of science and technology to which literature systems provide little or no direct access. The principal effort in fiscal year 1972 lay in defining the scope and objectives of the program, which will concentrate upon determining data requirements and characteristics in various fields and in supporting the development of methods and techniques that will be broadly applicable to computerized data system activities.

PUBLICATIONS

The objectives of the Publications Program have been changed substantially in view of the growing economic pressures confronting scientific publications, particularly the professional journals. Heretofore, the program had subsidized the publication of periodicals and monographs on the basis of scientific value and the need for Foundation support to ensure their survival. Hereafter, it will concentrate much of its support upon innovations in the form or method of publication — innovations designed to reduce costs and increase the utility of the documentation. Assistance in the publication of essential monographic works will continue on a limited scale, but will emphasize data compilations, critical reviews, and other such documents that serve to condense or evaluate the growing bulk of scientific literature.

RESEARCH

In recent years, the Research Program has devoted most of its resources to two university centers for information research: The Ohio State University and Georgia Institute of Technology. When this support was terminated in fiscal year 1972, it made available more funds to support specific projects aimed at defining and solving problems affecting the information-transfer process. The determination of priority needs and the development of a framework for future support will permit more productive application of the funds available in the program.

FOREIGN SCIENCE INFORMATION

The primary objective of the Foreign Science Information Program is to facilitate communication between U.S. and foreign scientists by arranging for translation of foreign materials and by supporting U.S. participation in international information activities.

The program relies upon contracts in countries where foreign currency holdings can be applied to the translation requirements of the U.S. Government — specifically those of the Foundation and the 13 other Federal departments and agencies whose needs the program coordinates and administers under Public Law 480. In fiscal year 1972, 70,000 pages of foreign science material were translated for use by the U.S. science community.

INTERNATIONAL SCIENCE ACTIVITIES

In fiscal year 1972, the Foundation continued or increased its support of major international programs such as the International Biological Program, the International Decade of Ocean Exploration, the Global Atmospheric Research Program, and Polar Programs. Accomplishments under these programs are summarized on pages 36 to 42 of this report. In addition, the Foundation (1) served as executive agency for eight bilateral research and exchange programs with the following countries: Australia, Republic of China, France, India, Italy, Japan, Romania, and Spain; (2) agreed to serve as executive agency for cooperative science programs with Argentina, Brazil, Mexico, and Iran; (3) started new cooperative science programs with Romania, Hungary, Czechoslovakia, and Bulgaria; (4) supported U.S. participation in the planning and development of the International Institute for Applied Systems Analysis; (5) supported U.S. scientific cooperation with most of the nine excess currency countries; and (6) started a new program, Scientists and Engineers in Economic Development, in conjunction with the Agency for International Development.

The Foundation also supported about 900 American scientists to visit foreign laboratories, plan international programs, and attend scientific meetings abroad.

The programs and activities summarized (right) are administered by the Foundation's Office of International Programs.

INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES

Summary of Activities—Fiscal Year 1972

Name of Program	*Activity*
United States-Australia Agreement for Scientific and Technical Cooperation	One seminar on rangeland ecosystems held in Adelaide, Australia. One short-term U.S. visitor funded to visit the University of Sydney.
East Europe Cooperative Science Program	Seven research projects initiated in cooperation with Romania; 13 Romanian scientists visited the United States, and five Americans visited Romania. A joint symposium on science policy with Bulgaria was funded.
France-United States Exchange of Scientists	Eight U.S. scientists received awards to study in France and eight French scientists received grants to do research in the United States.
India-United States Exchange of Scientists	Nine U.S. scientists traveled to India, and six Indian scientists came to the United States.
United States-Italy Cooperative Science Program	Two seminars were held in Italy, one on proteins and one on variable-structure systems.
United States-Japan Cooperative Science Program	Twenty-five seminars were held; 11 grants were made for visiting U.S. scientists; supplemental support was provided for 17 existing grants; and an exchange of eminent American and Japanese chemists was supported.
United States-Republic of China Cooperative Science Program	Fourteen short-term and six long-term visits were made by U.S. scientists; one seminar was held in Taiwan on forest ecology and genetics and one seminar on hurricanes and typhoons was held in Miami, Fla.; and a grant was made to the Asia Foundation to support U.S. specialists in Taiwan.
General Agreement for Friendship and Cooperation between the Governments of the United States and Spain	Ten Spanish scientists visited the United States and eight Americans traveled to Spain; scientific equipment was requisitioned for all approved projects.

The National Academy of Sciences (NAS), with NSF support, exchanged scientists with the Academies of Sciences of the U.S.S.R., Bulgaria, Czechoslovakia, Hungary, Poland, Romania, and Yugoslavia. The number of U.S. and foreign visitors and the man-months for each are summarized below:

United States-U.S.S.R. and East Europe Academy Exchange Program

	Visits Each Way *			
	Persons		Man-Months	
Exchange Country	United States	Foreign	United States	Foreign
U.S.S.R.	27	26	69	79
Bulgaria	8	5	12	12
Czechoslovakia	12	5	41	14
Hungary	11	5	25	18
Poland	10	6	20	34
Romania	16	11	44	32
Yugoslavia	13	10	33	33
Totals	97	68	244	222

* For the period April 1, 1971, to March 30, 1972.

In February 1972, the NAS negotiated a new exchange agreement with the Soviet Academy of Sciences, increasing the man-months of exchange from 180 to 216 man-months in each direction for the 1972-73 biennium. In May 1972, the NAS and the Polish Academy of Sciences agreed to increase the man-months of exchange from 40 to 50 man-months in each direction in the exchange year 1972-73.

The Foundation awarded a grant to the American Association for the Advancement of Science (AAAS) to support an exchange of four scientists annually between the AAAS and the Soviet All-Union Society "Znaniye." The visiting scientists will lecture on both scientific and "science and society" topics.

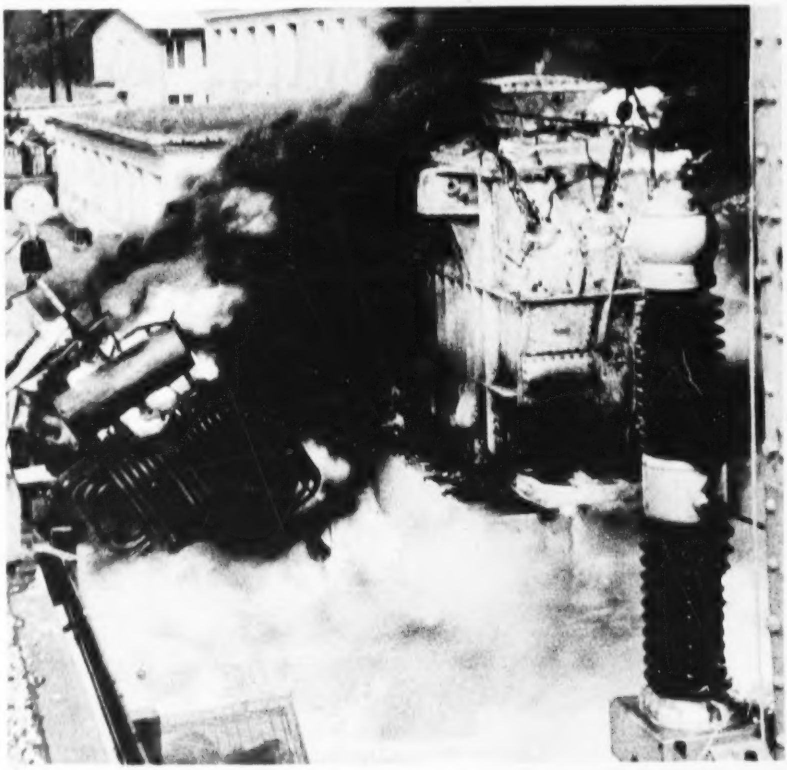
INTERNATIONAL ORGANIZATIONS

Foundation funding, through the NAS and other organizations, supported U.S. participation in international cooperative science activities conducted by both governmental and nongovernmental science bodies. The Foundation supported the Academy's participation in the planning and development of the International Institute for Applied Systems Analysis (IIASA). Representatives from the founding nations (France, East and West Germany, Italy, Poland, the United Kingdom, the United States, and the U.S.S.R.) met to prepare a charter, select a site, develop a program, and discuss institute membership. IIASA is expected to be formally established in late 1972 to begin work on urbanization, transportation, communication, pollution, and other complex problems common to industrialized nations.

SPECIAL FOREIGN CURRENCY PROGRAM FOR SCIENTIFIC RESEARCH AND RELATED ACTIVITIES

During fiscal year 1972, the Foundation awarded 23 grants for cooperative research projects in excess currency countries and made 106 travel awards to U.S. scientists to attend meetings, develop projects, and visit or work in laboratories in eight of the nine excess currency countries (Burma, Egypt, India, Morocco, Pakistan, Poland, Tunisia, and Yugoslavia; no project or travel awards were made for activities in Guinea). The Foundation supports these programs and activities with the U.S.-owned excess currencies which accumulate to the credit of the United States through the sale of agricultural commodities, the repayment of loans, and the payment of interest on loans. The commitment to the program by participating excess currency countries was demonstrated in fiscal year 1972 by Egypt and Yugoslavia, both of which converted currencies in amounts equal to particular NSF grants to dollars to purchase scientific instruments and equipment (mostly of U.S. manufacture) for cooperative projects.

A random example of the types of projects supported under the Special Foreign Currency Program is a study conducted by U.S. and Yugoslav electrical engineers on the characteristics of internal overvoltages of high voltage electrical systems. An understanding of the causes of overvoltages and methods to prevent them will assist both countries in reducing the frequency of failures and breakdown of equipment and lower the cost of constructing transmission towers, insulators, and other electrical equipment.



A burning transformer resulting from a voltage overload, part of a study conducted by United States and Yugoslav electrical engineers on the characteristics of internal overvoltages of high-voltage electrical systems.

Research Applications

The Research Applications Directorate administers two programs: Research Applied to National Needs (RANN) and the Intergovernmental Science Programs (ISP). In these activities, special emphasis is placed on exploration of technical opportunities that can lead to improvements in economic growth and productivity, to new products and services, and to improvements in our capabilities to deal effectively with social and environmental problems; and on developing mechanisms for transferring research results to programs of State and local governments.

The total NSF support of research that could properly be classified as applied research was approximately $71 million in 1972. This was an increase of about $22 million, or 45 percent, over 1971. The Foundation supports this applied research primarily under the RANN program which consolidates NSF's major problem-focused research efforts. Some applied research is also supported under Research Project Support, National and Special Research Programs, Computing Activities in Education and Research, the National Center for Atmospheric Research, and other activities. The increase over the prior year was a reflection, principally, of growth in the RANN program and of expanded support for research projects in the atmospheric sciences, engineering, and materials research.

The RANN program supports research on selected social, environmental, economic, and technological problems of national importance with the objective of contributing toward their practical solution. In fiscal year 1972, the RANN program funded 341 projects, for a total of $53.8 million, in 14 broad problem areas.

The Office of Intergovernmental Science and Research Utilization focuses on the development of improved programs and institutions for making science and technology available for use by States and local governments in solving problems. The work includes the use of results from RANN and other NSF programs that have important applications to those programs. The office also develops strategies for the utilization of RANN research results at all levels of government and in the private sector. In fiscal year 1972, this office sponsored 43 projects for a total of $1.0 million.

ADVANCED TECHNOLOGY APPLICATIONS

The projects of Advanced Technology Applications are designed to stimulate the development and application of new technology that can create new industries and markets for U.S. goods and services, as well as help improve national productivity and environmental quality. Major emphasis is given to research projects concerning energy systems to meet future national needs; earthquake engineering technology to better withstand the forces of earthquakes; de-

Table 6
Research Applications Obligations
Fiscal Years 1971 and 1972

(Millions of dollars)

	Fiscal Year 1971		Fiscal Year 1972	
	Number	Amount	Number	Amount
Research Applied to National Needs	213	$33.95	341	$53.76
Advanced Technology Applications	122	14.65	166	18.91
Environmental Systems and Resources	48	9.25	98	19.45
Social Systems and Human Resources	15	7.10	25	10.72
Exploratory Research and Problem Assessment	28	2.95	52	4.68
Intergovernmental Science Programs	28	.80	43	1.08
Total	241	$34.75	384	$54.84

velopment of new techniques for fire protection, prevention, and suppression; and development of new instruments to monitor environmental pollutants.

Energy Problems

Activities of the energy resources program fall into two general categories: (1) surveys and analyses of energy resources and research; and (2) support of specific research and development projects that will have direct impact on the energy problems of the nation.

In order to assess the problems associated with energy production, conversion, and use, it is necessary to bring to a focus information from an exceedingly broad set of disciplines. These range over such areas as reactor engineering, coal technology, economics, and political science. To provide the NSF energy program with a base for its program efforts, and to help the nation assess the magnitude of its future energy problems, the Foundation in the past year has sponsored several background studies.

A survey of current energy research in the United States was carried out by the Oak Ridge National Laboratory. This was the first comprehensive survey to be undertaken which included both Federal and privately sponsored research. Questionnaires were sent to all industries involved in any way, and to all Federal agencies. The resulting bibliography, with abstracts, contains almost 5,000 entries, cross-indexed for ready reference. (*Inventory of Energy Research*, Committee on Science and Astronautics of the U.S. House of Representatives.)

Factual material relating to national energy problems was summarized in a two-volume report, *The U.S. Energy Problem*, prepared by Intertechnology Corp. and available from the National Technical Information Service (NTIS). This report brings together in one place summaries of the results of many previous studies concerning energy, and attempts to systematize the approach to determining potentially high impact energy research needs. An example of these works is a projection of future U.S. energy requirements. A total of 56 separate projections were combined to obtain an estimate of the way in which U.S. total energy and electrical requirements may be expected to increase throughout the remainder of this century. The consensus of the projections is that demand for energy in all forms will grow at an annual rate of 2.8 percent, while that for electrical energy will alone grow at a rate of 5.5 percent. The assumptions behind all the projections may, of course, be subject to question. Nevertheless, the Intertechnology study provides a comprehensive survey of existing ideas and of present energy technology.

To assess needs for research in the energy area, Resources for the Future, under an NSF grant, identified research requirements in areas of energy consumption, production, technology, environmental effects, and policy issues. The study, prepared in collaboration with the MIT Environmental Laboratory, indicates specific problems in these areas which are likely to prove important in the coming years. (*Energy Research Needs*, available from NTIS.)

Environmental aspects of energy use are becoming increasingly important. This area was singled out for special attention through a workshop on Energy and the Environment conducted by Cornell University. The workshop brought together experts from a number of relevant fields to discuss four problem areas: (a) social, environmental, and health costs of energy use; (b) technological options for energy supply; (c) growth rates of energy demand; and (d) institutional mechanisms for dealing with environmental problems associated with energy use. (*Cornell Workshop*, available from the U.S. Government Printing Office.)

The second category of Foundation energy resources activities includes projects such as work on land use, power plant siting and power transmission, solar energy, and thermal energy storage. The University of Minnesota is developing a system aimed at the economical use of solar energy for generating electric power. The system will use a solar concentrator which focuses solar energy on a heat pipe with a selective optical coating. The heat pipe then conducts high temperature thermal energy via a heat transfer loop to a thermal storage unit; then the energy is released to the power cycle working fluid. L. O. Krampitz of Case Western Reserve University is investigating the feasibility for direct formation of hydrogen using sunlight and the photosynthetic process of plants in combination with the enzyme hydrogenase. This process may make it possible to produce economically useful supplies of hydrogen gas.

A coal gasification program was established at City College of New York (CUNY) in June 1972 with Arthur M. Squires as principal investigator. Advanced chemical engineering techniques are being studied that can lead to a markedly increased ability in the gasification of coal. These techniques can also facilitate the reaction of coal with hydrogen to produce extraordinary amounts of methane and aromatic liquids such as alcohols and turpentines. The program at City College should provide a basis for the design of pilot reactors for making hydrogen and other gases from coal or coke.

Earthquake Engineering

A major new thrust in earthquake engineering during the past year has been directed to technology transfer and utilization. The National Information Service for Earthquake Engineering had previously been established to collect, organize, and disseminate information. This activity has been augmented by a program aimed at the translation of earthquake engineering research into criteria, specifications, and methods usable by professional engineers and builders.

Projects undertaken to develop improved building practices and to make that knowledge available to State and local officials may help prevent future tragedies such as those caused by the San Fernando earthquake of 1971.

Current building practices concerning land use planning, building codes, and inspection of new and existing buildings do not generally reflect the newest knowledge of responses of buildings to earthquake forces. Organizations participating in this National Information Service have undertaken a program that will: (a) synthesize current knowledge and develop improved building practices for assuring the safety of new and existing buildings; (b) make this knowledge available to State and local officials for land use planning and building regulation to mitigate the effects of earthquakes, high winds, and explosions. Objectives of the program will include greater human safety, protection of property, and maintenance of vital functions under disaster conditions.

The Disaster Mitigation Project comprises three phases leading to improved building practices: evaluation of current building methods, development of improved methods, and implementation of these improved methods. Results from the first phase include reports defining best current practice; needs of decision-makers and professional users for land use planning, design, and evaluation of existing buildings; and significant gaps in knowledge which require research.

Improved practice will be developed in phase two, using results of new research; and phase three involves dissemination of the developed methodologies to the intended users, including State and local officials and Federal agencies.

Fire Research

Little is known about exactly how fire victims die, except in the obvious cases of severe burns, heart attacks, or fractures. In an attempt to determine how people become victims of the byproducts of fires — smoke and confusion — a grant has been made to the Applied Physics Laboratory of Johns Hopkins University to conduct a cooperative study with the Baltimore City Medical Examiner's Office and the university's School of Hygiene and Public Health. They are trying to reconstruct the sequences of events in fatal fires, finding out what the victims were doing, how much warning they had, how they reacted to it and, using results of post mortem analyses, what the causes of death were.

A related program at the University of Utah is studying the physiological and toxicological effects of smoke produced during the combustion of polymeric materials. The research team includes medical staff members and participants from the Salt Lake City Fire Department and the Fire Marshal of the State of Utah, and also the National Bureau of Standards. The program is concerned with problems connected with the burning

Firemen and researchers are working together to investigate sites of fires in efforts to determine the sequence of events that results in loss of life.

of polymeric materials such as fabrics, coatings, elastomers, and cellular plastics. The research will provide the fundamental information necessary to develop improved fire-resistant materials and to devise better testing procedures to evaluate material hazards under realistic conditions.

Instrumentation Technology

The application of research principles in the design, construction, and use of instrumentation is a key factor in the achievement of an increasingly high standard of living in the nation and in its role of world technological leadership. It is the purpose of this program to support research projects leading to new uses for and improvements of instrumentation for environmental, social, and technological systems.

The support of the application of new techniques to the problem of environmental monitoring included four new projects. At MIT, tunable semiconductor lasers will be applied to the detection of molecular atmospheric pollutants. At the University of California, Davis, the use of X-ray fluorescence, which is being successfully applied to large-scale aerosol monitoring in California, will be developed further for quantitative analysis of biological and physical samples of environmental interest. A group at the Lawrence Berkeley Laboratory is developing a portable instrument for the quick and easy determination of trace concentrations of heavy metals such as mercury in biological samples such as tuna. This instrumentation uses the recently invented atomic-absorption method called atomic Zeeman effect for analysis of trace elements in organic materials in the part-per-billion range. The measurement takes less than one minute and does not require prior chemical separation of the mercury from the host material. Such rapid examination can prevent large economic losses in such industries as fishing. A research team at the University of Oregon is presently applying a technique of low temperature physics as an aid in the study and monitoring of air pollution. The technique being studied is the quantitative use of a cold trap at liquid nitrogen temperatures. Such a trap can collect hundreds of different types of compounds for later analyses. This technique has the potential for reducing costs and increasing the sensitivity of air pollution measurements.

New instrumentation for improved medical diagnosis and more effective health care delivery systems is being developed in two areas. The first area of instrumentation and techniques for cancer radiotherapy involves four separate projects at Stanford, Harvard, Oak Ridge National Laboratory, and the University of Nebraska. These projects apply novel technology to the development of instruments for the treatment of localized cancer with neutron, proton, and negative pion radiation. Supporting studies, making extensive use of computer techniques, consist of determining the depths that doses of such radiations penetrate into tissues, as well as the relative biological effectiveness for various types of radiation. The second area of instrumentation for improved medical diagnosis and treatment includes four projects at MIT, Stanford, and the University of California, San Francisco. One of the two MIT projects and the Stanford project will study the diagnostic value of magnetic fields produced by the heart and the brain. The second MIT project will develop a magnetically propelled catheter for possible use in treating diseases of the brain. At the University of California, a new type of camera, consisting of multiwire proportional chambers, will be developed as a diagnostic device for the imaging of positron-emitting radioisotopes.

Advanced Industrial Processing

Enzyme technology and extractive metallurgy have been selected as areas where expected return on the research investment is great and where rapid progress is vital to the nation. Some grants for enzyme technology have been given to large interdisciplinary teams focused on particular problems. At MIT, work is under way to develop new techniques involving enzymes for the synthesis of complex organic compounds, in particular the synthesis of the antibiotic gramicidin s. Synthetic biochemical reactions are not currently practical for industry because the necessary enzyme co-factors, which are molecules that facilitate the transfer of energy or electrons, cannot be reused. Large-scale economic regeneration of co-factors and immobilization of several enzymes for coupled reactions present formidable scientific and engineering problems, and about one-third of the grantees are addressing aspects of co-factor enzymatic processes. A team at the University of Pennsylvania has immobilized a co-factor, designed a highly sensitive enzyme electrode for detecting phenol, and developed an enzymatic method for destroying phenol in waste waters. Several grantees are investigating various new industrial uses of enzymes, some of which have been patented. Support for processes for extractive metallurgy was initiated on a modest basis in fiscal year 1972, primarily for systems analysis of existing procedures and for research on automatic control. Highest priority is given for new processes which not only are economically attractive, but which avoid the air and water pollution problem usually accompanying existing technology.

ENVIRONMENTAL SYSTEMS AND RESOURCES

In efforts to direct scientific talents towards solving environmental problems, 98 projects were selected with investments of $19.4 million in fiscal year 1972. These studies deal with problems of weather modification, environmental aspects of trace contaminants and regional environmental issues, rural-urban development, impact of man on semi-primitive areas, land use allocation, and waste management strategies. They are set up in such a way that the specific users of the research results affect the formulation and conduct of the investigations. Such involvement of beneficiaries in the scientific activities helps make the objectives more real and the results more practical.

Mathematical Modeling for Environmental Issues

Environmental problems are usually complex and involve many factors and competing interests. As a result, environmental issues often arise from competition over the use of space or resources. With the use of mathematical models, available research data can be analyzed and used in planning and helping select among alternative solutions.

A team of computer researchers at the Harvard School of Design, led by Carl Steinitz, is developing methods for incorporating qualitative and quantitative environmental values into regional planning for an area southeast of Boston. Dr. Steinitz' work in computer graphics will provide a foundation for a two-dimensional, spatial planning model that will cope with problems such as regional water supplies, wetlands protection, solid waste disposal, land use allocation, and location of industrial, shopping, and residential structures and transportation corridors.

At Iowa State University, Earl Heady has developed a linear programming model of some 5,000 equations which he is applying to determine the impact of national agricultural practices upon water quality. This approach will help evaluate the environmental effects of alternative practices and policies. A parallel project led by Russell Thompson at the University of Houston is examining the probable quantitative demands for water in the future by chemical industries. Schedules of demands for both disposal and consumptive uses of water will be based on marginal values implied by the production functions generated for each of the 50 most important chemical products. Such predictions for the next 3 decades will then help develop policy to guide the development of water-using industries in specific regions.

Information from programs of the International Biological Program is being used by RANN research groups in efforts to develop management strategies concerned with the use and conservation of natural resources. At the University of Washington, Colorado State University, and Oak Ridge National Laboratory, investigators are adding economic, engineering, and sociologic parameters to ecological simulation models in order to develop models for better management of forest and grazing lands. The use of management gaming techniques with a computer can be an important element in helping instruct decision-makers on the probable consequences of their actions.

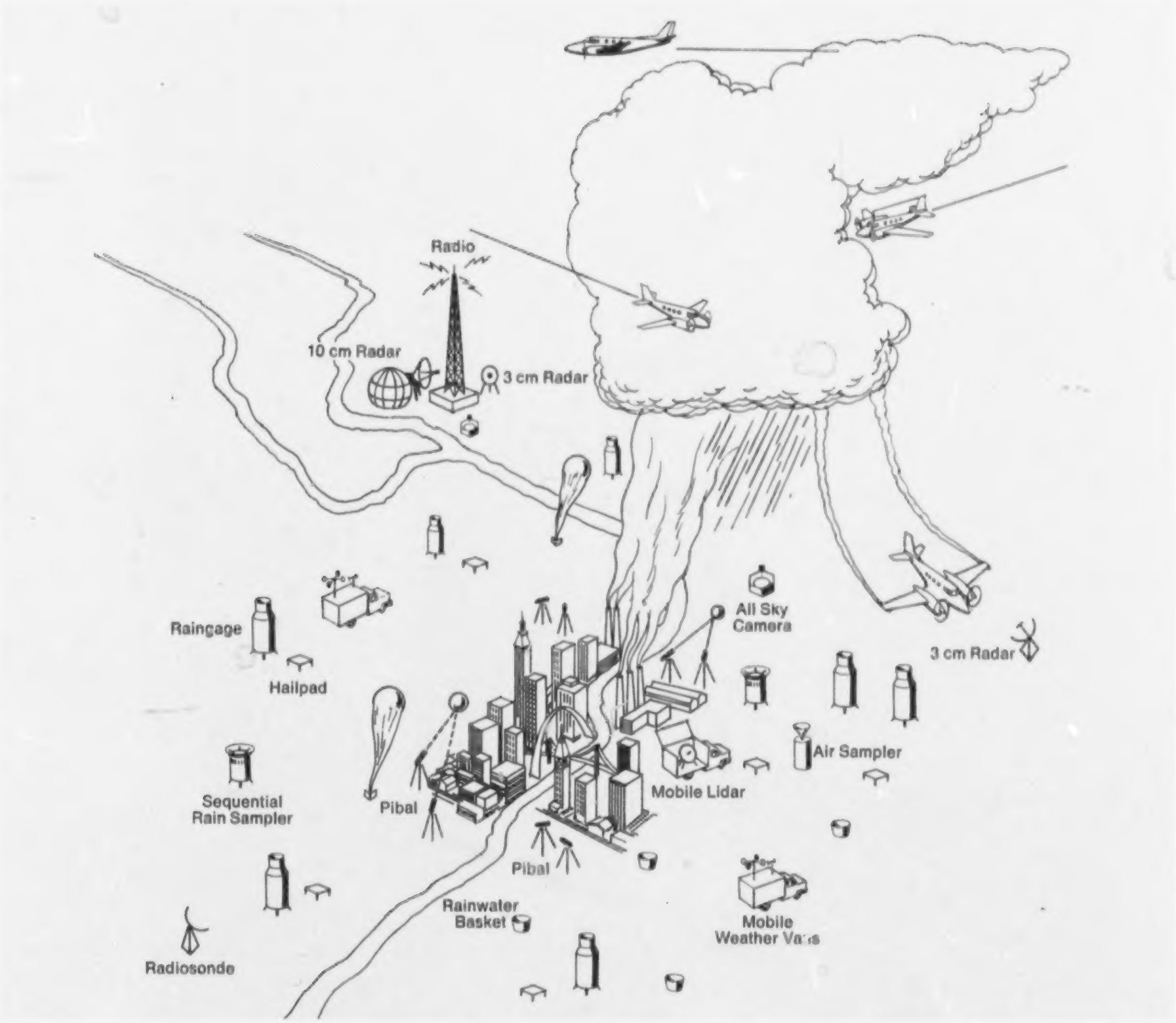
Water Management in the Southwest

A multi-institutional project is examining the environmental impact of various activities, including development of major coal reserves, recreational opportunities, and water resources in the Lake Powell region of Utah and Arizona. In a coordinated program, natural and social scientists and professionals in law and medicine are studying such phenomena as lake eutrophication, heavy metal contamination, stream flow, erosion and evaporation, air quality and epidemiology, as well as recreation, economics, and legal factors. The purpose of the project is to provide an improved scientific basis for water resource management taking into account users in the Lake Powell region, ranging from local Indian populations to heavy industry.

One result of studies on Lake Powell is based on a computer model which utilizes chemical analysis of water samples to calculate ionic composition and activity. These results show that calcite is precipitated as water plants withdraw carbon dioxide from surface waters, and that this calcite settles to deeper, more acid waters where it is dissolved. During the autumn and winter turnover of lake waters, a portion of this calcite may accumulate in bottom muds, thus representing a permanent withdrawal of calcite from the lake and from the Colorado River below the Glen Canyon Dam.

Weather Modification by Urban Centers

The role of atmospheric pollutants in influencing weather patterns is not clear at this time, but evidence is growing that the impact of man's activities upon the weather is an important factor and must be recognized and understood more fully. Scientists at the Illinois State Water Survey are studying the effects of urban centers upon local weather patterns. A study of the St. Louis area has indicated increases in precipitation, lightning, and hail in the summertime which are believed to be urban-induced, but winter weather patterns show little urban-induced effects. An analysis of the Chicago area indicated urban-related increases in both warm and cold season precipitation within the city and as far as 35 miles downwind of the city. Initial studies of Indianapolis have provided some slight evidence of an urban effect upon precipitation in the warm season, but no noticeable effect in the cold season. Another initial study of the Washington, D.C. area indicated a rather pronounced and consistent increase in both the summer and winter precipitation across the urban area.



Effects of atmospheric pollutants from urban centers on local weather patterns are being studied in a joint program undertaken by Argonne National Laboratory, University of Chicago, Illinois State Water Survey, and University of Wyoming.

Lead—A Trace Contaminant

Lead is an acknowledged toxicant to man and other animals. The sources of lead found in the environment, the routes and rates of transport, and the ultimate fate, including health hazards, are the subjects of investigation by three university teams.

Half of the lead dispersed into the environment and 95 percent of atmospheric lead is probably from gasoline additives and is in a particularly mobile form. Atmospheric lead concentrations are closely correlated with traffic density. Typical values range from 1 microgram per cubic meter in rural areas to more than 40 in a vehicle tunnel. Concentrations in solids decrease rapidly with distance from highways.

The major thrust of a University of Illinois team is to develop predictive models that describe the mobilization and transport of lead, especially from automobiles, in a 76-square-mile ecosystem. Food chain analysis and physiological effects are measured. A Colorado State University team is concentrating on the evaluation of atmospheric transport, solubility, and mobility.

The recent opening of what has become the world's largest lead mining and smelting district in the Clark

Several studies are being made on the sources, routes, and impact of lead pollution on the environment. In one of the projects, the rural area surrounding the new lead mining and smelting industry in southeastern Missouri is being analyzed for effects of lead on the vegetation, soil, and water. (Photo by American Metal Climax, Inc.)

National Forest of southeastern Missouri has afforded an unusual opportunity to study the effects of lead and associated metals in a forested ecosystem. A team at the University of Missouri at Rolla is collaborating with the U.S. Forest Service, the Geological Survey, and the mining industry to identify all lead pollution processes associated with mining, smelting, and transport to the consumer. This investigation includes the use of remote sensing for detection of contamination in plants, especially sulfur dioxide toxicity emanating from the smelter.

The efforts of the three research groups constitute a coordinated study of lead in the environment. The investigators exchange samples of lead-containing soils and plant and animal tissue for calibration as well as results. They also coordinate with similar projects studying other heavy metals such as cadmium, at Purdue, and mercury, at Stanford and Rochester. They are also assisted by analytical studies of toxic metals and by the toxic materials information center at Oak Ridge National Laboratory.

SOCIAL SYSTEMS AND HUMAN RESOURCES

The major aim of research supported in Social Systems and Human Resources is to provide reliable information and analysis to guide policy decisions and to illuminate the consequences of alternative social policies and programs. There are two major programs in the division: 1) Municipal Systems, Operations, and Services; and 2) Social Data and Community Structure.

Research on municipal systems is concerned with improving the existing use of urban resources, with evaluating the social consequences of new technology, and with evaluating the benefits and costs of alternative organizational forms for our cities. This research includes studying methods to improve such operations as refuse collection, police force activity, health care delivery, and new urban transportation systems.

The social data and community structure program is concerned with developing information on changing trends in the U.S. population and data required for evaluating social programs and policies. This involves analyses of the criminal justice system and efficiency of law enforcement agencies, as well as a search for ways to improve the public decisionmaking processes at all levels of government.

The division allocated $10.7 million in fiscal year 1972, with 66 percent supporting research on municipal systems and 27 percent on social data and community structure; grants were made with an average size of $43,000 and an average duration of 18 months.

Solid Waste Management in New York City

The Urban and Policy Sciences Program is continuing its research on urban problems in collaboration with municipal agencies in New York City through an award to the State University of New York at Stony Brook. Principal attention is being given to

Trying to ease problems like those of solid waste collection and disposal in New York City, a team of scientists at the State University of New York at Stony Brook is studying methods for more efficient public services in crowded cities.

systems analyses of the collection and disposal of solid waste in New York City. The Stony Brook team has provided the city and sanitation workers union with plans for improved manpower schedules which have been adopted for implementation. The city's Environmental Protection Administration estimates substantial savings for the city as a result of the more efficient allocations of available manpower. The Stony Brook group is also studying the effectiveness of district court systems in Nassau County and is developing techniques for measuring the productivity of public services.

Analyses of Urban Growth

Results from an exploratory award to the RAND Corp. for research on problems of urban growth and development in San Jose suggest that the most important influences on development have been Federal procurement policies and Federal income tax policy. These provide large incentives for new residential development but little for rehabilitation of older housing sites. Because of these influences, the range of decisions open to municipal officials is restricted.

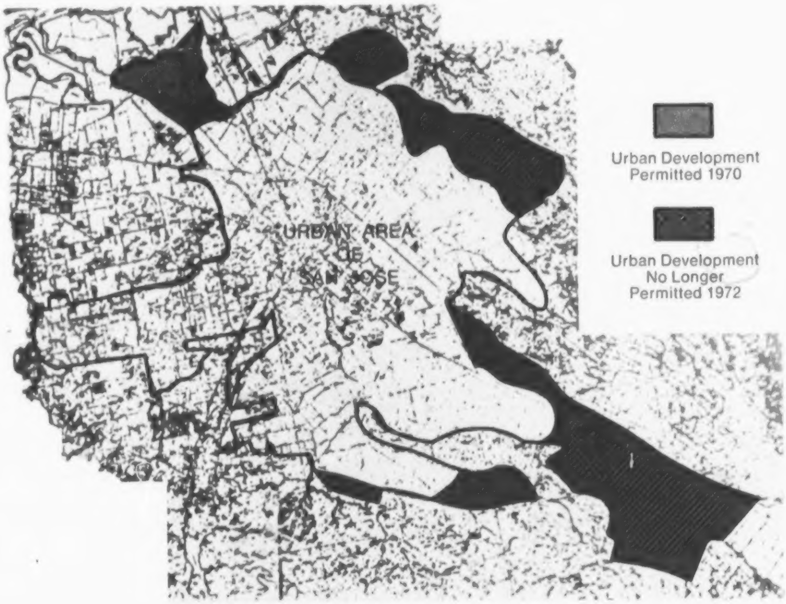
The RAND Corp. is continuing its research on urban growth in San Jose and, in collaboration with local universities, has begun related research in Seattle and St. Louis, with the aim of specifying how Federal policies affect the growth and economy of differing urban areas.

Clearinghouse and Laboratory for Census Data

A clearinghouse and laboratory have been established at the Center for Research Libraries in Rosslyn, Va., to make efficient use of the large amount of computer data assembled during the 1970 Census of Population. More than 2,000 reels of tapes are being processed and edited, and programs are being developed to make the data more accessible for study. Training and advice will be provided to researchers in the social sciences and other fields in the use of census data for research and planning.

Social Costs of Natural Disasters

A group of researchers of the University of Colorado has begun a systematic analysis of 15 types of natu-


URBAN AREA OF SAN JOSE
Urban Development Permitted 1970
Urban Development No Longer Permitted 1972

Development planned for San Jose, Calif., was restricted in five areas after analysis by the RAND Corp. showed that the cost of delivering services, such as police and fire protection and street and park maintenance, and utilities, such as sewers, water service, and storm runoff facilities, would create a large drain on the resources of the city.

ral hazards to determine their incidence, the social and economic costs associated with them, and to examine remedial steps which might lessen the costs of damage from these natural hazards.

EXPLORATORY RESEARCH AND PROBLEM ASSESSMENT

Exploratory Research and Problem Assessment is an attempt to define, analyze, and explore emerging national problems relating to technology and the health of the economy, to human and social needs, and to the future trends of the nation's growth. Emphasis is placed on systems-oriented studies of the impacts of science and technology on society and of national policy alternatives.

Exploratory Research

This program supports the early stages of research into problem areas where there are significant and pressing public policy issues. For example, the development of a citizen feedback system for Statewide environmental planning is being explored by the Environmental Planning Information Center in Montpelier, Vt. Public educational materials will be drawn from both Government environmental agencies and the citizen groups concerned with environmental problems. Information on citizen attitudes and their environmental concerns will be provided to executive agencies, to legislative bodies, to the citizen groups, and to the general public.

The potential for improved efficiency of small- and medium-scale manufacturing by automating parts programming is being studied by the University of Rochester with the collaboration of an industrial partner, the Gleason Works. An important intermediate objective is improvement of engineering graphics practices. Three fundamental problems must be solved: extraction and compaction of information from mechanical drawings and specifications; synthesis of processing sequences from that information; and sequence implementation for machine control. The desired results are part-programming software systems linked closely to engineering record-graphics systems, and prototype systems that can be tested in an industrial environment.

Problem Assessment

Research efforts in this program are intended to assist in defining and analyzing national issues in a broad context, to synthesize existing knowledge and identify specific opportunities for research to aid decision-making and policy processes.

The protection of privacy of personal information in data banks is an important issue being addressed by the RAND Corp. of Santa Monica. This research involves mathematical investigations of the theoretical possibility of creating a data bank with perfect invulnerability to invasions of privacy. It also is analyzing bounds on the achievability of perfect data privacy and technical and procedural means of achieving a desired level of data privacy. Formation of the foundations of a cohesive theory of information privacy is under way, and the RAND Corp.'s 1969 Computer Privacy Bibliography is being updated. The research is proceeding toward derivation of functional relationships among security, costs, and performance for various data security techniques, such as access codes, privacy transformations, and special security features in operating system programs.

The needs of society in dealing with the moral and ethical implications of behavior control are being investigated by a task force established by the Institute of Society, Ethics, and the Life Sciences at Hastings-on-Hudson, N.Y. The research will be conducted by a multidisciplinary group including scientists, ethicists, policy experts, and others. Individual experts or groups of experts will gather information and develop position papers for examination and evaluation by the panel of the institute.

Researchers at Carnegie-Mellon University are investigating means to improve consumer safety through innovative consumer education. They are attempting to develop instructional modules for high schools to prepare consumers to make better decisions in the marketplace with respect to product safety. The researchers will determine consumer attitudes and level of knowledge concerning safety, and what technical concepts and guidelines should be transferred to consumers to enable them to understand and develop an overall approach for intelligent buying and safe handling of products. The research will also provide manufacturers and Government agencies with a description of the appropriate information needed by the consumer to make more deliberate, intelligent, confident buying decisions. Finally, the investigations will evaluate the effectiveness of teaching modules in accomplishing their goals. This experimental approach will use the skills of engineers, educational specialists, and behavior specialists, with the cooperation of a commercial television station.

Technology Assessment

Technology assessment studies are intended to explore systematically the impacts of technological intrusions on society. For example, the impacts of four biomedical technologies are being assessed by the Committee on Life Sciences and Social Policy of the National Academy of Sciences: 1) *in vitro* fertilization for human reproduction; 2) predetermination of the sex of children; 3) retardation of the process of aging; and 4) technologies for the modification and control of behavior. The information developed by the Academy will be published in book form. The book will attempt to illustrate, by example, one approach to the assessment of biomedical technology. It will also try to develop some general principles for the assessment of biomedical technologies and to offer suggestions for the institutionalization of assessment procedures.

Technological impacts frequently cause widespread public alarm. Case histories of such instances are being examined by the Midwest Research Institute, Kansas City, Mo., in an interdisciplinary research project on the properties of such "unstructured technology assessments." The program involves the preparation of the histories of a minimum of 100 cases occurring during the past 25 years. Consequences of the cases will be studied in detail to derive understanding of the full nature of the associated impacts or consequences on society. Particular attention will be given to early warning indications of public alarm and to effective remedial actions.

Two survey studies of technology assessment activities are nearing completion. "Technology and Public Policy: The Process of Technology Assessment in the Federal Government" has been studied by the George Washington University. A broader survey of the extant technology assessment activities at various levels of government, industry, and private institutions has been accomplished by Peat, Marwick, Mitchell, and Co., of Washington, D.C.

INTERGOVERNMENTAL SCIENCE AND RESEARCH UTILIZATION

NSF's Intergovernmental Science Programs assist State and local governments in strengthening their capabilities to foster and support the development and use of scientific methods and technologies.

These programs are administered in close coordination with the President's Office of Science and Technology and the Office of Intergovernmental Relations in the Office of the Vice President as these offices move ahead with implementing the intergovernmental aspects of President Nixon's Science and Technology Message of 1972. Continuing relationships are maintained with the National Governors Council on Science and Technology and with the Science and Technology Committee of the National Legislative Conference. Close relationships also exist with the national instrumentalities of State and local governments in planning and administering activities in this area.

Objectives of the Intergovernmental Science Programs include improving communications, identifying and assessing needs for science and technology, testing new mechanisms to encourage the use of science and technology, and disseminating and diffusing results of studies and demonstrations.

Among the State-level activities, a grant was awarded to the Ohio State University Research Foundation for the design and implementation of a planning and decision information system for the Governor of Puerto Rico. The system is serving as a prototype for other such State systems. A planning grant was awarded to California for the design of a comprehensive mechanism to aid the State in bringing science and technology to bear upon domestic problems. A pilot project was initiated with the Pennsylvania Science and Engineering Foundation to extend to local governments the technical assistance services of a university-based technology applications program.

To implement the President's science and technology message, six conference studies on Statewide research and development priorities were supported in Ohio, Oklahoma, Georgia, Pennsylvania, California, and Puerto Rico. These studies will serve to identify R&D needs and capabilities, the potentials offered by science and technology to State government operations, and the areas where Federal-State partnership activities might be enhanced. Funds were also provided for the partial support of a National Action Conference on Intergovernmental Science Policy held in Harrisburg, Pa., cosponsored in part by the U.S. House of Representatives Science and Astronautics Committee. Several projects were approved in the area of academic public service, including a 3-day conference conducted by the National Association of State Universities and Land Grant Colleges. Support was provided for an Academic Resources Council in South Dakota which involves all of the State's institutions of higher education. In order to strengthen the relationship between scientific and technological research and State government operations, a program administered by the Massachusetts Department of Community Affairs will involve graduate research students from a number of Boston area institutions with activities of the Commonwealth.

Additional activity in the programs involving State legislatures was undertaken during the year with an initial grant to the State of New York Assembly to provide partial support to the Assembly Scientific Staff and to fund public policy research by cooperative graduate student and professor groups.

Increased emphasis was placed upon activities to aid local governments in their use of science and technology in decision-making and program operations. An industry-related aerospace technology applications program was initiated during the preceding fiscal year in Fresno, San Jose, Anaheim, and Pasadena. Building on this program and two projects at Auburn University and the University of Missouri, which use the expertise of displaced engineers and scientists, grants were made to support two other models designed to enhance the use of science and technology in the local government setting. One of these models will address self-initiated institutional change for increased science and technology impact in Tacoma, Wash.; the other will test out ways of maximizing the utility of voluntary activities conducted within the framework of a municipal science and technology advisory committee in Philadelphia.

During the fiscal year, two particularly significant studies were published dealing with intergovernmental science policy. The first of these reports, *Power to the States—Mobilizing Public Technology*, was the product of an Intergovernmental Science Program-supported study conducted by the Council of State Governments. The other report, *Public Technology—A Tool for Solving National Problems*, was transmitted to the Federal Council on Science and Technology by its Committee on Intergovernmental Science Relations. These studies have added greatly to the understanding of the field of intergovernmental science policy.

During the year, responsibility for assuring the utilization of research results developed by RANN was assigned to the Intergovernmental Science Programs Office, and the name of the office was changed to reflect this new responsibility. This function will be accorded high priority in the activities of the office in the coming fiscal year.

Science Education

New national priorities together with changes in public attitudes toward science and the education of science manpower have been reflected in the Foundation's programs supporting science education. With emphasis on innovation and improving the quality of science education, the refocusing of the Foundation's education activities, following the pattern which took clearly defined shape in fiscal year 1971, has continued at an accelerated pace. This new pattern has among its major goals:

- developing science education programs aimed at providing an appropriate number, variety, and quality of scientific and technological manpower;
- stimulating a greater interest in and understanding of science among a broader spectrum of today's students and the general public; and
- improving the effectiveness of science education in terms of the nation's financial investment therein.

Clearly, the nation's educational system has for several years been under great stress. Rising enrollments have brought with them at all levels a wider variety of students with a wider variety of abilities and a wider variety of goals. These efforts, together with new student attitudes about the purposes of education, have forced institutions to adopt new practices and adapt programs to new and far more complex situations. Some of the changes have resulted in better education, others have not; some have been responsive to real needs, others have been far wide of the target. During this same time period, costs of education have increased markedly, resulting in increased taxes, increased tuition charges, and depleted institutional financial resources.

The Foundation cannot, of course, provide even a small fraction of the funds needed to pay the increased costs related to science education. It can, however, by judiciously targeted investments aimed at developing, testing, and promoting better courses and curricula; at identifying appropriate uses of new educational technologies;

Table 7
Education in Science
Fiscal Year 1972
(Dollars in thousands)

	Number of proposals received	Dollar amount requested	Number of awards	Funds obligated
Science Education Research, Development, and Demonstration				
Alternative Instructional Methods and Materials				
Curriculum and Instruction Development	64	$14,500	39	$ 3,469
Science Curriculum Improvement	51	8,000	38	4,618
Advanced Science Education	59	4,400	49	2,255
Experimental Models and Demonstrations				
Resource Personnel Workshops and Conferences	70	3,100	46	1,359
Comprehensive In-Service Teacher Education	11	3,800	11	3,364
Pre-Service Teacher Education	22	4,600	11	1,511
Technician Education Development	41	7,000	11	1,251
Student-Originated Studies	284	4,400	103	1,896
State and Urban Systems	3	1,700	2	1,680
Instructional Improvement Implementation				
Training Educational Personnel for Implementation				
Secondary School Teachers Programs	1,365	76,700	544	18,330
College Teachers Programs	461	19,500	207	3,182
School System and College Implementation				
Cooperative College-School Program	479	21,100	151	4,355
College Science Improvement Program	158	37,900	49	9,067
Instructional Scientific Equipment Program	1,529	15,000	372	2,881
Talented Students				
Student Science Training	525	9,200	124	1,938
Undergraduate Research Participation	1,015	14,000	311	3,860
Graduate Student Support				
Fellowships	6,199*	39,100	1,550*	9,897
Traineeships	1,808*	11,000	1,808*	10,443
Presidential Internships	728	5,100	570	3,925

* Applications—not proposals.

and at assisting in dissemination of information about and implementation of new and innovative kinds of programs, stimulate higher quality science education which will at the same time result in a higher ratio of benefits to costs.

In fiscal year 1972, therefore, groundwork was laid for more specific reorientation of certain already existing programs and for development of new activities within a structure targeted along three principal lines: Science Education Research, Development, and Demonstration; Instructional Improvement Implementation; and The Talented Student. There has been, in addition, a separate program of Graduate Student Support. Under these four headings, the Foundation conducted educational activities in fiscal year 1972 to meet the new changes and demands placed on the nation's scientific and engineering communities.

SCIENCE EDUCATION RESEARCH, DEVELOPMENT, AND DEMONSTRATION

Research, development, and demonstration encompass two main lines of activity. The first is the development of alternative instructional methods and materials. The second involves experimental models and demonstrations. Together these provide the cutting edge of new innovations in science education. Through them the Foundation seeks to redirect and revitalize the teaching of science and technology for both those who will pursue a career in these fields and those who need a sufficient knowledge of them to conduct the complex affairs of society more effectively.

ALTERNATIVE INSTRUCTIONAL METHODS AND MATERIALS

Essential to the improvement of science education is support for the development and testing of new teaching materials, courses, and curricula at all levels—pre-college, college, and graduate. At all three levels, increasing attention is being given to newer disciplines and interdisciplinary fields, and to materials and educational programs appropriate to the broader spectrum of students within the educational system.

Curriculum and Instruction Development

During fiscal year 1972, the Course Content Improvement Program, aimed at pre-college levels of education, became the Curriculum and Instruction Development Program (CID). The new name reflects more accurately the interests and functions of the program, which is concerned not only with development of courses and curricula, but with research in various areas including learning, the structure of educational organization and evaluation, and with development of more effective means of instruction.

The major effort within the program was to consolidate previous attainments with respect to out-of-school activities, vertical integration, and new models of school organization. Plans are to support additional work in all of these areas as well as in the areas of research and learning. Two areas given special attention in the CID program were Science Education Outside of School Walls and a Political Science Curriculum Study.

Three grants have been made to support Science Education Outside of School Walls. The Smithsonian Institution received a grant to develop an experimental touch exhibit for the purpose of investigating whether guided handling of real objects of natural beauty could indeed lead visitors to the kinds of curiosity and insights in learning about natural science that do not occur in the usual museum situation. A grant was made to the Palace of Arts and Science Foundation (San Francisco) for the development of a series of participatory exhibits for the Arts and Science Exploratorium, which is unique in its emphasis on sensory perception. The University of California, Berkeley, was awarded a grant to provide support to the Lawrence Hall of Science for a project to develop instructional models for outdoor education of students, ages 11 to 15.

Fiscal year 1972 also saw the initiation of what may turn out to be a major curriculum development in the area of political science through a grant to the American Political Science Association for a curriculum development effort at both the elementary and secondary school levels. Although the major theme will be political science, much material from

Table 8
Curriculum and Instruction Development Program
Financial Support by Discipline
Fiscal Year 1972

	Biological sciences	Mathematics	Physics	Social sciences	Inter-disciplinary sciences	Multi-disciplinary sciences *	Other science	Totals
Elementary	$ 27,000	$191,750	- 0 -	$ 49,400	$722,089	$ 702,011	- 0 -	$1,692,250
Intermediate	178,450	22,800	- 0 -	- 0 -	5,000	601,123	- 0 -	807,373
Secondary	78,650	165,200	$15,300	1,073,204	99.500	885,291	$11,000	2,328,145
Totals	$284,100	$379,750	$15,300	$1,122,604	$826,589	$2,188,425	$11,000	$4,827,768
Percentages	5.9	7.9	.3	23.4	17.0	45.3	.2	100.0

* Includes Resource Personnel Workshops and Administrators' Conferences.

a variety of social and behavioral science areas will be incorporated. This interdisciplinary spread within the general areas of social and behavioral sciences is also evident in material being prepared under two grants to Education Development Center for continuing support of the Exploring Human Nature Project.

The distribution of program funds by discipline in fiscal year 1972, as seen in table 8, shows the emphasis on the social and behavioral sciences. Of the $3.5 million recommended for the usual kinds of activities supported through the Curriculum and Instruction Development Program, $1.1 million or 23 percent was in grants identified as social science.

Science Curriculum Improvement

New demands on science require continued improvement in undergraduate science curricula. In fiscal year 1972, initial grants were made in support of large-scale projects capable of significantly altering the way undergraduate science is taught. Among these projects were The Experimental Approach in Undergraduate Engineering, at Illinois Institute of Technology; Computer-Based Teaching Techniques in Undergraduate Science and Engineering Education, at the University of Texas, Austin; and the Biology Core Co-Tie (BIO-COTIE) Program, at Colorado State University.

The intent of the IIT project is to completely restructure the undergraduate engineering curriculum. The traditional classroom lecture approach will be abandoned entirely and replaced by a program of project-oriented studies. Problems of a broad scope will be posed to project groups composed of from four to 15 students. The factual information needed will be made available in modules developed to enable and encourage self-instruction. Thus, the faculty members can concentrate on those teaching activities requiring personal interaction with students.

At the University of Texas, Austin, a concentrated effort will be made to provide computer-based instruction on a university-wide basis. Twenty-three individual projects in 18 departments in the colleges of engineering and of arts and sciences are involved, but with the significant characteristic that all of these involvements are to be integrated and correlated with one another.

The BIO-COTIE project at Colorado State University is designed to upgrade the sophomore biology offerings of all of the 2-year colleges in the State of Colorado, and to ensure that biology graduates of these schools can proceed directly to advanced work at 4-year schools. To supplement their own course materials, the 13 community colleges involved will be provided with a great deal of supportive instructional material, much of it in the form of videotapes prepared by both CSU and 2-year college personnel. The focus of interest in this project, like the one at the University of Texas, is the use of specially prepared materials in a widespread and integrated fashion.

Advanced Science Education

Support for the development of alternative kinds of doctoral-level degree programs began in fiscal year 1970 and continued this year with four grants. One grant will assist the University of California, Los Angeles, in inaugurating a new 5-year program leading to a Doctor of Environmental Science and Engineering degree. This program is intended for students with undergraduate degrees in any field of natural science and engineering who wish further education in the application of scientific and engineering technology to existing and anticipated environmental problems.

Another award went to the University of Illinois at Chicago Circle for a doctoral program to produce college teachers. Based in the biology, chemistry, and mathematics departments, this program will incorporate various communications methods and education technology in the design of new instructional systems.

The University of California, Berkeley, with the help of NSF funds, is developing a new Ph.D program in the Graduate School of Public Policy. A feature of this program is that in their second year, groups of four or five students join groups of at least three faculty members from different fields in "syndicates" to study substantive policy areas such as the technology of police service delivery or income maintenance systems. The ultimate objective of this approach is to provide the nation with needed professionals who can furnish policymakers with analytical materials necessary to reduce the degree of un-

Under a grant to Worcester Polytechnic Institute for a program akin to that at Illinois Institute of Technology to implement a new flexible curriculum, students pursue independent study projects. These students perform air pollution measurements in an industrial complex. (Photo by Worcester Polytechnic Institute) certainty that currently attends the public policy formation process.

Michigan State University received a grant in the Advanced Doctoral-Level Program to provide partial assistance for the development of a 3-year sequence of activities in scientific instrumentation. This sequence is intended to make available to students of many science departments an instrumentation minor in their Ph.D programs.

A grant to the University of Denver was one of five new projects initiated during 1972 directly concerned with the development or strengthening of master's-level programs intended to meet critical needs. The College of Law and the Graduate School of Arts and Science have inaugurated a new Master of Science degree in Law and Society. An innovative feature of the program is the provision for a practice program enabling the students to teach law at the high school or college level and also to pursue legal activities in a variety of community settings. Three other projects in this category involve a joint M.S. program in Engineering and Public Administration, at New York University; the development of computer-aided instructional materials and time-sharing procedures as part of an M.S. program in economics, at Florida Atlantic University; and a new design-oriented M.S. program at the State University of New York at Buffalo.

Continuing education at the graduate level was supported through a grant made to Stanford University to carry out experiments with and to assess television techniques expected to be widely used in the future. Stanford now operates a four-channel Instructional Television Network with a two-way audio capability between the originating classroom and remote sites in the San Francisco Bay area.

Five awards were made in the category of Interdisciplinary Student-Originated Research Training (ISORT). As was the case in fiscal year 1971, all were concerned with environmental or social problems. These projects involved planning for meteorological and pollutant networks in California, being carried out by a team of three UCLA students; social cybernetics and computer-based communications media by two graduate students at the University of Illinois; problem-solving in urban playgrounds by three CUNY students; and population density and social pathology in selected areas in New York City, by a team of Queens College students.

The fifth ISORT project was a study at Stanford University on Mass Media Coverage of Environmental Problems, carried out by students in the School of Medicine and the Department of Communication.

EXPERIMENTAL MODELS AND DEMONSTRATION

While the Foundation is unable to support full-scale implementation of new courses and curricula throughout the country, it is prepared to take the intermediate step of establishing models and demonstration projects in which new materials, techniques, and instructional modes can be tried out and subjected to careful evaluation. In this way, new courses and curricula can be managed and publicized so that their characteristics and value as teaching and learning mechanisms will be clearly evident. Included also are some of the Foundation's most recently initiated activities, still being operated as "experiments," and to be continued pending more thorough evaluation of their usefulness. Within Experimental Models and Demonstrations are activities targeted at all levels of education.

Resource Personnel Workshops and Conferences

Resource personnel projects are designed to inform pre-college supervisory and teaching personnel about prospective new curricula. Supervisor Projects include short courses which provide the information necessary for educational decision-makers — principals, directors of education, and other school administrators — to conclude whether or not to adopt specific curricula changes for their school systems. They also give these supervisors the necessary background to support their teachers should these new curricula be implemented. Other pre-college resource personnel projects include a course of 3 to 4 weeks' duration, with some follow-up in the Academic Year Institutes Program discussed later. A major focus of these projects is to provide leadership training for implementing new curricula. Such projects typically bring together a team consisting of a science educator, a school administrator, and a teacher to take the course, after which they assist their home school district in adopting the curriculum improvements.

In addition to funding the distribution of information about newly developed courses and curriculum materials and providing courses on them, NSF supports conferences directed toward planning the cooperative development oı new courses. At these conferences, scientists, educators, and educational technology experts plan concise materials and curricula that can be fully developed in appropriate teacher-training institutions. Students in pre-service teacher education programs at these institutions help with the design, development, and testing of these materials. Together, the 20 grants for these administrators' conferences and the 26 grants for the resource personnel projects provide various degrees of background or training for nearly 2,700 participants in fiscal year 1972.

Table 9
Resource Personnel Workshops
and
Administrators' Conferences

Total Number of Requests	70
Total Dollars Requested	$3,109,991
Total Dollars Granted	$1,358,562
Resource Personnel Workshops	
Requests 41	2,652,226
Granted 26	1,086,930
Administrators' Conferences	
Requests 29	457,765
Granted 20	271,632

Comprehensive In-Service Teacher Education Projects

The primary objective of these comprehensive grants is to offer in-service training opportunities for teachers who will become an integral part of the teacher education program of the participating institutions. Support, normally provided for a 4-year period with renewal grants on a yearly basis, is offered to institutions which show evidence that changes induced by the projects are likely to persist beyond the period of the grant.

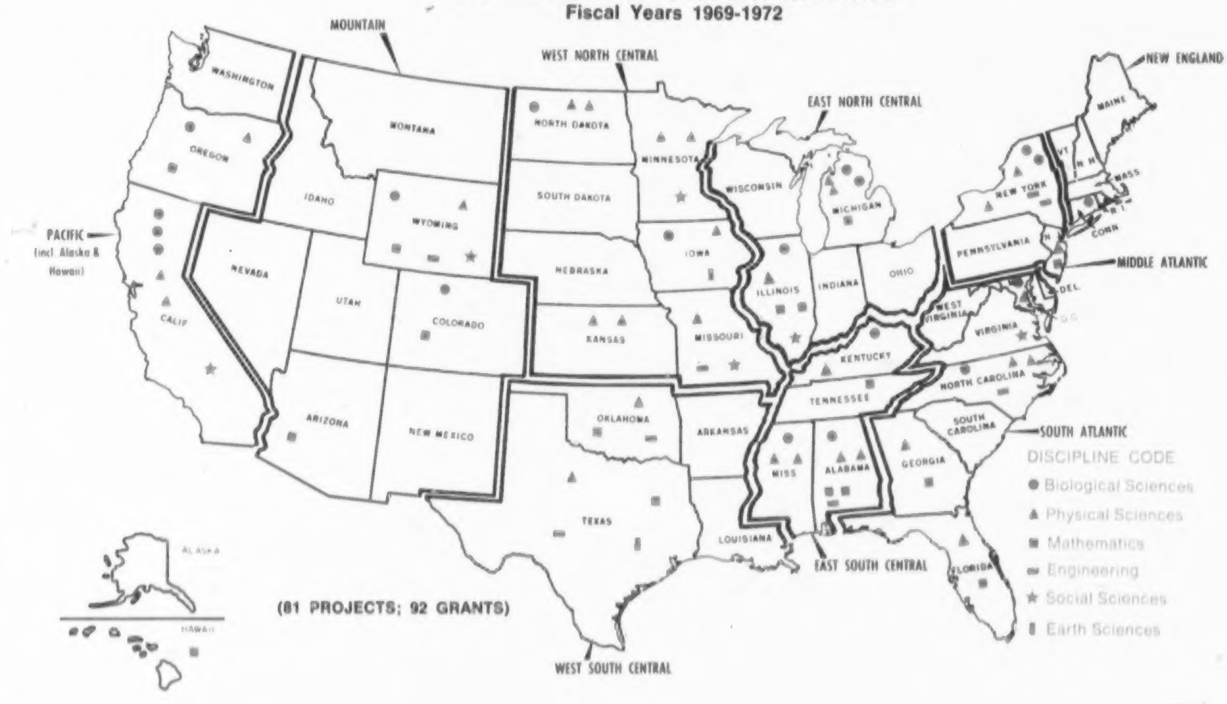
During the past year, five supplemental grants were made for comprehensive projects initiated last year at the University of Notre Dame and San Jose State College (mathematics); the universities of Mississippi and South Dakota (biology and chemistry); and the University of Wyoming (physical sciences). In addition, three new projects were funded at the University of Arkansas (mathematics); California State College at Fullerton (science); and Virginia State College (biology and earth sciences).

The comprehensive grant awarded to the University of Wyoming provides an example of the way in which such grants foster a lasting interaction between the teacher training institution and the teachers in the region it serves. Under the project at Wyoming, a system of "portal schools" is being developed throughout that State and in neighboring States, designed to train teachers in newly developed curricula and materials, and staffed by teachers trained in summer and academic year institutes at the university. At present, there are 20 portal schools serving 920 teachers. A Science Teaching Center at the university serves as administrative center, library, and materials repository for demonstration and developmental work on courses and curricula. In addition, a distinguished professorial chair of science education has been established to enhance the prestige of science education and stress the high priority assigned to it by the university.

Pre-Service Teacher Education

In recent years, the Foundation has stressed improvements in the pre-service training of elementary and secondary school teachers as an economical way to decrease the need for their early retraining. This approach often requires extensive changes involving the entire curricula through which all students in the institution who are preparing to teach science receive their initial training. Its potential is exemplified in a pre-service education project begun some 3 years ago by the Physical Science Group at Newton, Mass., which has

Cooperative Projects for Two-Year Colleges
DISTRIBUTION OF SUPPORT BY STATE
Fiscal Years 1969-1972



produced instructional materials specially adapted for undergraduates who plan to become teachers of science in secondary schools.

Pre-service teacher education clearly involves a coordination of effort between higher education and elementary and secondary education. The same principle, that of recognizing seemingly separate elements as actually units of an overall educational system, is applied in the program of Cooperative Projects for 2-Year Colleges. In this program, the Foundation supports State or urban consortia of 2-year college science departments cooperating with neighboring university departments to improve the substance and quality of education. As a result, students may advance more efficiently to study at 4-year colleges and universities. Over 1,000 2-year college science departments in over 600 2-year colleges have benefited from these grants.

Technician Education Development

The Technician Education Development Program, which became operative during fiscal year 1972, is intended to provide a variety of instructional models. Ten initial grants have been awarded for projects to strengthen curricula and to establish new opportunities in both 2-year and 4-year colleges. The past year has seen a significant rise in the number of programs being offered by collegiate institutions for training technicians and technologists primarily for research. And there are indications that many colleges are making efforts to reach back into local secondary schools to make a career in technology more attractive. To encourage experimentation in this effort, a grant was made to Los Angeles Pierce College to develop a program in Computer Electromechanical Technology for interested 11th and 12th grade high school students. The experience gained in cooperative ventures of this sort should provide greater latitude in technical education and an improved relationship among all technical areas.

Student-Originated Studies

Still another type of model, one which shows considerable promise of influencing the pattern of student-teacher interaction, is developing in the Student-Originated Studies Program. Now in its second year of operation, this activity provides a large-scale test of the degree to which students are capable and ready to undertake self-instruction through self-designed and self-managed scientific investigations. In fiscal year 1972, grants awarded to 120 colleges and universities supported 103 student projects involving more than 1,300 undergraduate college students.

In addition to demonstrating students' readiness to assume increased responsibility for their own educational development, student-originated projects encourage college students to express productively their concern for the environmental and societal well-being of the nation. Some examples of this have been projects on:

- An economical way to force water into molecules so that waste glass could be formed into a commercially usable insulating material;
- A cheap and effective way to reduce stream pollution caused by runoff from farm feedlots; and
- Biological uptake of heavy metals in sediments washing down from old mines.

Many student-originated projects funded by this program have elicited wide public interest as reflected by their coverage in the news media.

State and Urban Systems

Two systems grants were made in 1972, a supplemental grant for the Systems Approach to Science Education in Delaware to support the second year's operation of the Del Mod Project, and an initiating grant for the Oregon System in Mathematics Education.

The Del Mod Project, which is a cooperative effort of the University of Delaware, Delaware State College, Delaware Technical and Community

Table 10
Student-Originated Studies
Distribution of Grants
Fiscal Year 1972

Region	Discipline Type				Total Number of Grants
	I	II	III	IV	
New England	2	5	2	2	11
Middle Atlantic	3	2	5	4	14
South Atlantic	3	4	7	3	17
East South Central	0	2	0	3	5
East North Central	5	4	4	5	18
West North Central	2	2	1	4	9
West South Central	0	1	3	1	5
Mountain	3	3	1	2	9
Pacific	5	3	4	3	15
	23	26	27	27	103

Discipline	
I. Resource Utilization Studies	23
II. Water Quality Studies	26
III. Urban and Rural Studies	27
IV. General Environmental Studies	27
	103

These three groups are conducting projects as part of the Student-Originated Studies Program. (Top) Students at Virginia Polytechnic Institute are establishing space criteria and design criteria that may influence the behavior of pre-school children. (Center) Another VPI group is assessing effects of pollutants on the ecology of a stream. (Bottom) A University of California, Riverside, team is studying the geological, economic, and social implications of earthquakes incident to the San Jacinto fault. Seismic measurements help them give specific fault location data to homeowners, contractors, and highway officials.

College, the Delaware State Department of Public Instruction, and the 26 school districts of the State, has as its objectives the development of better science courses, improvement of the qualifications of science teachers, and introduction of new teaching strategies.

A second systems grant in the amount of $1 million was made to the Oregon Educational Coordinating Council for the support of mathematics education in Oregon. The Oregon System in Mathematics Education is a coordinated Statewide project dealing with mathematics education in grades K-14, with a strong emphasis on instruction at the elementary level.

INSTRUCTIONAL IMPROVEMENT IMPLEMENTATION

Within this area of activity there are two principal lines of attack — one oriented toward training that will provide to educational personnel in the schools and colleges the background required to institute or implement course and curricular changes; the other providing support for implementation of new courses or curricula in a limited number of institutions, with the intent that these will serve as models for consideration by others.

TRAINING EDUCATIONAL PERSONNEL FOR IMPLEMENTATION

Activities within this category take into account the fact that implementation of new courses and curricula and introduction of new modes of teaching can be effected only in institutions in which the teaching faculty is already receptive to change. That faculty must also be competent to perform in a way that will ensure viability or at least an objective tryout of new instructional patterns. The intent, therefore, is to provide teachers and other personnel with the knowledge and understanding of new materials and the techniques of their planning and development necessary to achieve this goal. Since the nature of the educational process varies from level to level, there are activities directed at both pre-college and post-secondary personnel.

Secondary School Teachers Programs

In addition to classroom study in courses designed to meet the needs of participants, the Foundation supports a number of summer and in-service institutes. Some focus on acquainting teachers with new course materials and assisting them in implementing these new materials in their classes. Others assist teachers in developing their own course materials.

Many teachers are inadequately prepared to conduct field work with their students, hence, many institutes include field work; some are conducted entirely in the field. One summer of the Michigan State University 3-summer sequence in biology has been conducted at Gull Lake Biological Station. The University of Wisconsin System has provided a field institute in biology at its Pigeon Lake Biological Field Station and one in "environmental assessment" at its Clam Lake Field Station. The Iowa State University Institute in Field Studies in Earth Science has been conducted at Philmont Scout Ranch, Cimarron, N. Mex.; each participant in this institute has been given experience in practice teaching in the field through planning and his conducting instructional hikes with groups of Scouts. By contrast, the Illinois Institute of Technology institute in physics has been devoted to the "inner city"; its participants have been Chicago inner city teachers.

A combined Summer/In-Service Institute for physical science teachers in eastern North Carolina was designed and conducted jointly by Elizabeth City State University and East Carolina University. One of the purposes was "to provide a common goal for two state universities that have been working separately . . . for many years. The fact that the project involves a predominately black school and a predominately white school should help build lines of communication between students and staff of the two schools." The project staff is drawn equally from the two institutions.

The close in-service institutes (ISI) involvement in the implementation of new curricula was continued with the fiscal year 1972 program. Particularly noteworthy is the increase in the number of training opportunities allocated to social science, Engineering Concepts Curriculum Project, and Intermediate Science Curriculum Study materials. The seven Man: A Course of Study projects are to be involved in a national assessment, similar to the 3-year evaluation of earth science institutes undertaken by the Earth Science Curriculum Project at Boulder, Colo., during 1968-71. For the social sciences, the estimated distribution of participant opportunities by discipline was up from last year's 4.2 percent to 9.3 percent, which more closely approximates the 12.6 percent called for by the numbers of social science teachers.

In accordance with a policy instituted in fiscal year 1972, Academic Year Institutes (AYI) may have either a national or regional orientation, that is, they may draw participants from the country at large or from a carefully circumscribed geographic region such as a metropolitan area, a State, or a group of States. Regardless of the geographical scope selected, AYI participation is intended for well-trained teachers capable of moving into leaderhsip positions.

In fiscal year 1972, seven nationally oriented and 18 regionally oriented projects were awarded. Of the former, one is intended for in-service science supervisors, three for supervisor-trainees, two for resource personnel in mathematics, and one for economics education consultants.

College Teacher Programs

It is through summer institutes and short courses (including the new Chautauqua-type short courses) that the Foundation assists college teachers. An increasing proportion of current support by the College Teacher Programs is for projects in interdisciplinary areas, environmental controls, curricular innovations, and new approaches to teaching and learning. These programs are being used more and more to assist teachers in replacing outmoded curricula with major revisions of undergraduate course sequences. There is also a noticeable increase in the involvement of social scientists in the use of these programs to prepare teachers for implementing curricular improvements. The institutes and short courses supported in fiscal year 1972 include such topics as the application of micro-economic theory to public policy problems, the use of computer science in social and behavioral science research, and the applications of systems analysis to land use problems.

SCHOOL SYSTEM AND COLLEGE IMPLEMENTATION

School System and College Implementation activities are directed toward the support of actual implementation of change at both pre-college and post-secondary levels — for the former, indirect support (via colleges and universities) for implementation of new courses or curricula within a school or school system; for the latter, direct support to colleges and universities for reform of their science education programs.

Cooperative College-School Science

The Cooperative College-School Science (CCSS) Program assists schools and school systems in attaining substantive improvements in their science and mathematics courses and curricula. A planned project of 1 to 3 years seeks to provide the participating schools with a central core of teachers capable of introducing changes in classrooms involved. The projects supported by the CCSS program reflect the distinctiveness of the cooperating school systems and their needs, as well as the strength of their commitment to improve their science and mathematics programs.

The quality of projects to strengthen science education in elementary schools has improved steadily since 1967. The number of proposals has increased from 111 to 479; the number of projects serving elementary teachers alone has increased from 12 out of 56 (or 21 percent) to 69 out of 143 (or 48 percent), a trend the Foundation is seeking to encourage. Additional projects are training both elementary and secondary teachers. In the past 3 years, the CCSS program has supported 165 projects involving 8,768 participants in elementary curricula developed under Foundation grants: Science — A Process Approach (SAPA); Science Curriculum Improvement Study (SCIS); Elementary Science Study (ESS); and Man: A Course of Study (MACOS).

Since 1968, a considerable number of proposals have been received to improve science and mathematics education for the disadvantaged. Several of these proposals have been supported. Two such projects in 1972 have the primary objective of providing educationally and culturally disadvantaged junior or senior high school students with positive educational experiences which stress achievement and minimize failure. A basic assumption in each program is that poor motivation is a significant cause of low achievement by the culturally disadvantaged, that success in a high status subject will raise a student's self-image. One project at Purdue University involves development of audio-tutorial methods for implementation by 30 science teachers in the high schools of Gary, Ind. A second project at Southern Methodist University is training high school teachers and students from inner city schools in Dallas, Tex., in computer programming and data processing. The primary objectives are to improve the self-image of the students in a depressed area containing large percentages of minorities and to provide them with employable skills in computer science. A project at Northern Montana College will assist in bringing a coordinated activity-centered and inquiry-oriented elementary science curriculum to schools serving Montana Indian children

A unique project involves a grant to the Jericho Public School System, Jericho, N.Y., to assist in the implementation of the Science Curriculum Improvement Study program in grades K-6. The project is among a small number of experimental endeavors in the program to explore a variety of approaches to school system improvement. The commitment by the school system is extraordinarily strong. Every teacher in the system will be trained in one year, and a viable leadership cadre will be developed to sustain the program. The amount of Foundation support is a small fraction of the normal expenditure for such a project.

College Science Improvement

In fiscal year 1972, the College Science Improvement Program initiated the development of what may be the most innovative institutional model yet supported. Worcester Polytechnic Institute is developing an entirely new organization of its undergraduate instructional program. The project will involve the use of individually prescribed instruction in all courses; a computerized catalog of individualized student research projects, including many with the cooperation of off-campus agencies; and a new comprehensive evaluation system for the certification of students for degrees.

This project represents a significant departure from the usual pattern of support signaling a continuing move in the program toward phase-out of implementation support and increasing emphasis on developing nontraditional patterns of education. Typical also of this transition is a project at Bakersfield State College to develop a model institution for the California State College system, based on the construction of "learning villages." Such villages use faculty in new roles (primarily as resource persons to enable more meaningful interaction between "students and teaching") and employ modular units of instruction (typically in the audio-tutorial format) by the students themselves.

Another section of the College Science Improvement Program was initiated to accelerate the development of the science capabilities of predominately undergraduate minority institutions. Catch Up and Keep Up is the prevailing theme of the institutional developments supported by this section of the program. Changes in what is being taught as reflected by local curriculum revision, renovation of existing facilities, and acquisition of instructional equipment are the major elements in the plans currently being implemented. Fourteen institutions have been supported thus far involving both natural science and social science departments.

Instructional Scientific Equipment

The Instructional Scientific Equipment Program encourages implementation of course and curriculum improvements by providing necessary equipment. The program received 1,529 proposals in fiscal year 1972 involving requested funds roughly five times the amount available for allocation. Nevertheless, it continues to reach a broad spectrum of institutions; for many, including a substantial number of 2-year colleges, this experience for a small fraction of the program provides the only direct of science talent by providing special contact with the Foundation.

TALENTED STUDENTS

Although today there is no serious shortage of scientific manpower generally, it is quite possible that a few years from now (the period beyond which projections of manpower needs may be quite inaccurate) the situation may be quite different. Through the Talented Student Program, NSF supports steps to identify talented science-oriented young people currently in college and in high school and motivate them to remain committed to careers in science. The program has as its primary objective the conservation of science talent by providing special experience for a small fraction of the nation's highly talented science-oriented students. A second objective of almost equal importance is that of encouraging schools and colleges to alter their "regular" science programs to include more activities that give students an opportunity for choice, that lead them into problem-oriented study, and that place upon them more responsibility for their own learning.

Student Science Training

The Student Science Training Program (SSTP) is designed to provide academically talented secondary school students with educational experiences in science and mathematics beyond those available in high school or early college courses. It also brings outstanding students into direct contact with college teachers and research scientists of recognized competence.

Over the past several years, there has been a substantial increase in the number of proposals received in the program, but the support level has remained at about $2 million during this period, approximately the same as in previous years. One hundred and twenty-four proposals were supported this year at the funding level of $1.9 million for 4,300 students. Two general types of projects continue to be supported in this program: (1) Special Advanced Courses designed to give the student a unique experience in science and associated laboratory work which may include open-ended projects or laboratory assignments; and (2) Research Participation involving the student as a junior associate of a research team or as principal investigator on a problem of appropriate difficulty under the direct supervision of an experienced research scientist.

In 1972, the number of projects supported which were designed especially for students with limited educational opportunities increased from 25 percent to 38 percent of the total grants. Students in this category have demonstrated high potential, but come from secondary schools in which training is inadequate; these students may be located in inner city or in isolated rural areas and may belong to minority groups as well as to other segments of the educationally disadvantaged population. While all projects receive economically disadvantaged students of high ability, in 1972 eight were especially designed to meet the needs of these students.

Undergraduate Research Participation

Since 1959, the Foundation has been instrumental through the Undergraduate Research Participation Program in providing valid research experience to approximately 63,200 undergraduate students. In 1972, the program introduced some changes to broaden student participation; Ph.D.-granting departments were required to select at least 40 percent of their participants from smaller, neighboring institutions.

The program seeks to implant the research participation concept in institutions where it is not yet a regular part of the curriculum and to provide faculty members with the opportunity to exploit the potential for enhancing teaching effectiveness by placing major responsibility for learning upon the student. In 1972, grants were awarded to 208 institutions to support a total of 2,635 college students throughout the country.

GRADUATE STUDENT SUPPORT

FELLOWSHIPS AND TRAINEESHIPS

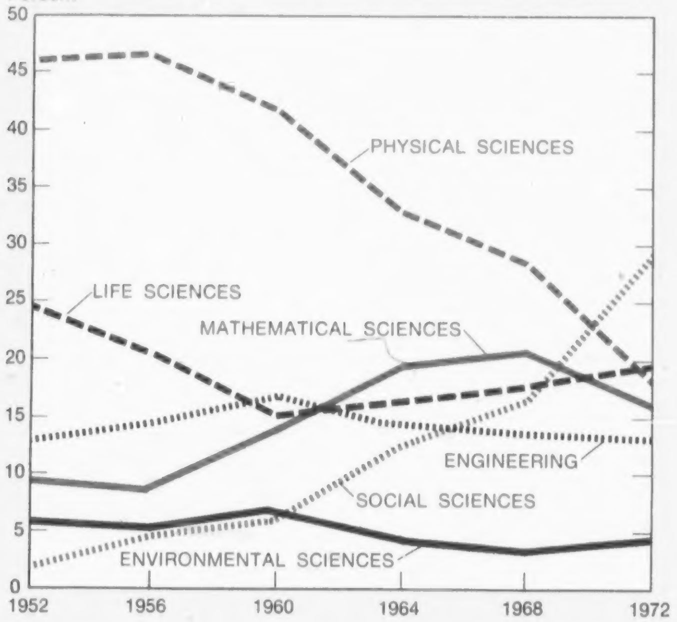
NSF's direct support of individuals through fellowships and traineeships which in prior years included young postdoctorals, college faculty, and advanced scholars, centered on the graduate student in 1972.

For the first time, 3-year awards were made in the graduate fellowship program. Previously, 2-year fellowships were offered to new applicants, with the option to apply for one or more years of additional support as needed. The new awards permit an individual, after completing the first year of tenure, to utilize the remaining 2 years over the following 4 years. Thus, for example, fellows may now interrupt their formal training for meaningful work experiences in industry and, on returning to graduate school, modify their academic programs to accommodate newly discovered, specific career objectives.

Of the 1,550 graduate fellowships offered in this year's competition, 550 are for 3 years; the remaining 1,000 awards represent second- and third-year fellowships for prior-year awardees.

NSF graduate fellows are selected on the basis of ability in national competition. Nevertheless, the distribution of awards by field of study closely parallels applicant interest, and this has undergone some shifting over the 21-year history of the program. Most notable is the decreasing proportion of awards in the physical sciences, principally chemistry and physics, accompanied by a significantly increased share of fellowships for the social sciences, especially since 1964 when full coverage of these fields was achieved. The phase-out of traineeships continued this year. The 1,808 awards made to 224 universities represented only commitments from prior years; fiscal year 1973 will

PERCENT DISTRIBUTION OF NSF GRADUATE FELLOWSHIPS BY FIELD OF STUDY FISCAL YEARS 1952-1972 (4-YEAR INTERVALS)



mark the final year of such commitments. The last new awards were made in fiscal year 1970.

PRESIDENTIAL INTERNSHIPS IN SCIENCE AND ENGINEERING

The Presidential Internship program was developed by the Foundation in September 1971 at the request of the Office of Science and Technology. Funds made available ($4 million) from the Department of Labor permitted the allocation of 570 internships to 81 federally funded R&D laboratories. Unemployed scientists or engineers holding a master's degree or higher and whose qualifications and promise were deemed by the recruiting laboratory to be clearly superior were assigned to internship activities which would facilitate their transition to future jobs needed by society. Of the stipend offered the interns, $7,000 is furnished by the Foundation and the remainder is from matching funds supplied by the laboratory. These 1-year appointments are nonrenewable.

A profile of appointments based on information from 262 interns in 46 installations shows that 50 percent of the interns hold a doctorate; 93 percent are male; 18 percent are veterans; and 66 percent were unemployed at the time of their appointments and the remainder were underemployed, temporarily employed, or students.

SCIENCE RESOURCES AND POLICY STUDIES

The overall objective of the Foundation's programs in science resources and policy studies is the development of the factual and analytical basis for national planning and policy formulation in the area of science and technology resources. The program encompasses the two closely related activities of analysis and data collection related to science and technology issues. The information developed through these studies is used in arriving at decisions concerning the NSF and national science efforts. Staff studies and analyses are supplemented with a program of grants and contracts conducted mainly with universities, other nonprofit organizations, and other Government agencies.

SCIENCE RESOURCES STUDIES

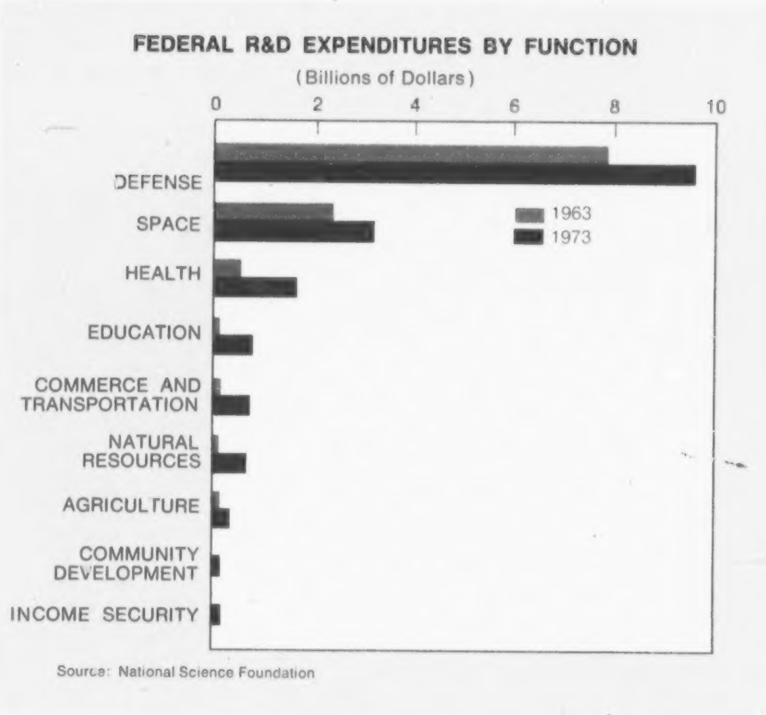
Science resources studies of general interest appear as NSF publications available at the Foundation or through the Government Printing Office. Appendix E lists those released in fiscal year 1972. The completed and ongoing studies described in the following section provide a brief sampling of the study activities conducted in this program.

Manpower

Manpower Characteristics System. The development of an alternative system to the National Register of Scientific and Technical Personnel was undertaken during the year in order that necessary information on the nation's science manpower would continue to be available. After consideration of a number of alternatives, in terms of coverage of population, capability to supply needed data, feasibility of development, and possible costs, the Manpower Characteristics System was chosen. This system will provide information which is representative of a defined population, will produce the essential data elements required by policy-makers, and is estimated to entail costs which are less than its predecessor.

The Manpower Characteristics System includes three major subsystems: a Comprehensive Doctorate Roster, based on existing National Academy of Sciences efforts; periodic surveys of an augmented sample of scientists and engineers, similar to the sample used for the 1972 Postcensal Survey; and a series of surveys of nondoctorate entrants to science and engineering. This last subsystem will be based on samples drawn from existing cohorts of college students now maintained by the American Council on Education.

Postcensal Manpower Survey. Late in fiscal year 1972, the Census Bureau, under NSF sponsorship, conducted a survey of a representative sample of 100,000 persons classified in the 1970 census as being in scientific, engineering, and technical occupations, or as having a college education. This project provided a once-in-ten-years opportunity to obtain national benchmark data for scientific and technical personnel by functional activities, types of employment, salaries, formal education, supplementary training, mobility, and their interrelationships, for a large sample.



Source: National Science Foundation

Research, Development, and Academic Science

Federal R&D Funding. The Foundation report *National Patterns of R&D Resources, 1953-72* estimated total U.S. expenditures for research and development in 1972 at $28 billion. This report also indicates that the number of scientists and engineers engaged in research and development declined in 1971 to 519,000 from the peak employment level of 559,000 in 1969. Most of this 40,000 reduction occurred in industry as a result of lower Government funding in the space and national defense areas, although miscellaneous nonprofit institutions and Government staff were also lower.

A more detailed report on Federal financing of research and development, which accounts for approximately 55 percent of total research and development, appears in the NSF report *Federal Funds for Research, Development, and Other Scientific Activities*, Volume XX. Federal R&D funding now is turning upward, after a period of decline that began in 1968.

Academic Research Price Index. The increasing cost of academic research is of major concern to both the universities performing research and the sponsors of such research, notably the Federal agencies. In the absence of price indexes directly applicable to academic research and development, administrators must depend upon more general indicators such as indexes of wholesale prices, consumer prices, GNP deflators, or professional salaries to estimate the extent of inflation in academic research expenditures. A staff study has sought to improve such estimates by developing an experimental price index of costs associated with such expenditures. The index so developed shows a considerably sharper rise in academic research costs than that estimated from the more conventional indexes.

Higher Education Panel. A new system was established to obtain rapidly, from a sample of universities and colleges, information needed for policy and planning purposes. NSF, with the co-sponsorship of the National Institutes of Health and the Office of Education, contracted with the American Council on Education to operate a fast response system known as the Higher Educational Panel (HEP). Among the surveys completed during the year were the following:

- *Changes in Graduate Programs.* A panel of institutions granting advanced degrees reported on the addition or elimination of graduate programs since 1970 and further modifications planned through 1974. Only about half as many new doctoral and master's degree programs in science and engineering are planned for the 1972-74 period as were added in 1970-72.

- *Field Enrollment of Junior-Year Students* (1970-71 *and* 1971-72). During January 1972, sample institutions were requested to report junior-year enrollments for fall 1970 and fall 1971 in certain designated fields. This information provides preliminary indications of career choice at the bachelor level. Survey findings indicate that engineering and the physical sciences generally suffered declines in junior-year majors, while the life and social sciences experienced increases between 1970 and 1971.

Graduate Student Enrollments. A timely report on graduate student enrollment in doctorate-granting institutions reported that first-year, full-time graduate science enrollment decreased 5 percent between 1970 and 1971 after declining 2 percent the previous year. Other major findings of the report included:

- The "top 20" graduate institutions experienced reductions in first-year, full-time enrollment at an above average rate — 8 percent.
- Virtually all areas of science experienced reductions in enrollment.
- The number of full-time graduate students supported primarily by fellowships and traineeships declined nearly 10 percent from 1970 to 1971.
- The proportion of full-time graduate students receiving their primary support from the Federal Government declined from 37 percent in 1969 to 32 percent in 1971.

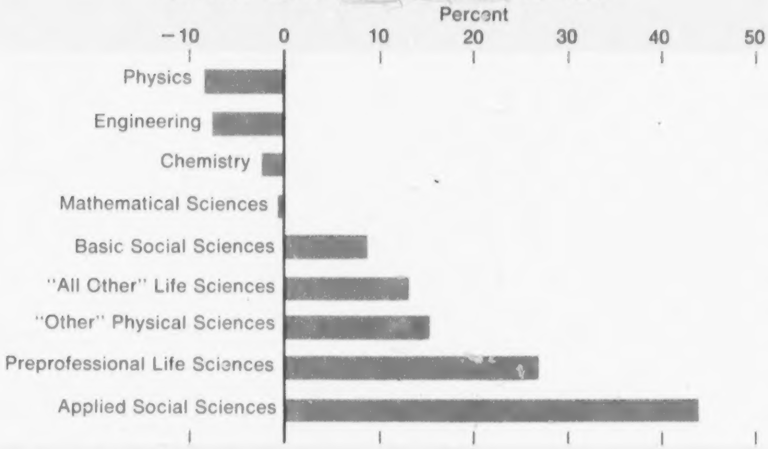
Industry

Basic Research in Industry. Late in the fiscal year, an intensive interview survey of industrial research officials was conducted in about 50 major R&D performing companies to identify the factors responsible for current changes in the nature and level of industrial research.

Small Business R&D Conference. In June 1972, the National Science Foundation joined with the Department of Commerce and the Small Business Administration to sponsor a national conference aimed at exploring the problems of the small R&D firm. Over 300 representatives of small business firms, universities, and Government met for 3 days to discuss such topics as Government Markets, Selling Research and Development to the Federal Government, Managing Financial Growth, and New Opportunities for the Small R&D Firm. The conference recommendations to improve the position of the small R&D firm are now being assessed.

Economics of Research and Development. Following the April 1971 symposium on the relationship of research and development to the economy, several studies seeking to clarify further these relationships have been funded. Among the studies now in process is a university-conducted series dealing with R&D relationships to innovation, marketing, and productivity in the service industries. A Conference Board study of the extent to which multinational U.S. companies conduct research and development abroad and related implications for this country will be completed in 1973. The National Bureau of Economic Research is investigating and attempting to develop measures of the relative economic returns attributable to private investment in research and development, to advertising, and to plant expansion. At the National Planning Association, researchers will examine some conventional production indexes to determine feasibility of adjusting them in order to take qualitative factors into account. The adjusted indexes, when related to R&D expenditures, may provide further insight into productivity trends.

PERCENT CHANGE IN MAJORS DECLARED BY JUNIOR-YEAR STUDENTS, 1970 TO 1971



SOURCE: ACE Higher Education Panel, *Survey of Enrollment of Junior-Year Students (Fall 1970 and Fall 1971)*

SCIENCE POLICY STUDIES

Activities of COSPUP-COPEP

The Foundation has continued support of the Committee on Science and Public Policy (COSPUP) of the National Academy of Sciences in their program to develop priorities for scientific research. Two major reports have been completed and published this year: *Astronomy and Astrophysics for the 1970's*, which examines the status of astronomy and develops priorities for research in both earth-based and space-based astronomy, and *Physics in Perspective*. The summary volume of this latter report contains recommendations for policy and program emphasis by both the scientific community and the sponsors of physics and describes a methodology for assigning priorities among various subfields and major programs in physics.

The Committee on Public Engineering Policy (COPEP) of the National Academy of Engineering evaluates current and foreseeable developments in the field of engineering and determines their relevance to the needs of society, as well as providing advice to the Foundation on policy matters to serve as a guide for establishing program priorities. During the past year, the Committee has devoted its efforts to four important areas: environmental impact statements, multidisciplinary problem-oriented research, environmental quality standards, and technological goals.

Committee on Radio Frequencies

The Foundation has also provided support to the Committee on Radio Frequencies of the National Academy of Sciences. This committee, which maintains close contact with the Inter-Union Commission on Frequency Allocations for Radio Astronomy and Space Science (IUCAF), has proven significant in providing advice for policies for the assignment of radio frequencies and in assisting in planning for the use of the radio frequency spectrum.

Other Planning Activities

Support was provided for a research team at MIT to conduct a study of possible policy alternatives for science. A major result has been the development of a manpower model for engineers and physicists. This model has successfully fitted historic manpower curves and is capable of being used for predictive purposes.

As part of a Government-wide program to identify new technological opportunities, the Foundation supported activities examining the process of innovation and looking for specific problem areas or technologies that were ready for exploitation.

Evaluation Activities

The National Academy of Sciences assisted the NSF with a survey and evaluation of the nature and urgency of needs for equipment, instrumentation, and facilities in ten science and engineering disciplines. The evaluation showed clearly that there is a pressing need for equipment in the $10,000 to $300,000 price range in university science and engineering research centers, equipment which, with few exceptions, would improve the quality and increase the output of research programs in these institutions without requiring additional manpower. Importantly, the needed equipment would frequently make possible the exploration of new and promising lines of research otherwise virtually impossible.

Other evaluation activities under way in fiscal year 1972 include a system dynamics study of the doctorate manpower market, to determine the impacts of alternative policies on the future balance between supply and demand of doctoral scientists; and development of a computerized budget model which allocates NSF funds for any specified or proposed budget to a given State, region, or institution, and to scientific disciplines. Other studies included development of a methodology for the use of citation and publication counts as measures of research productivity and a study of implications of social and technical developments on the supply of and demand for R&D technologists. In addition, an evaluation of the terminated Science Development Program has been initiated to ascertain whether and to what extent the program accomplished its objectives and how effectively it aided the recipient institutions.

UNIVERSITY SCIENCE PLANNING AND POLICY

The Science Policy Research Section of the Division of Social Sciences has some 21 currently active grants whose objectives are to support the field of science policy research and to develop a core capability in the United States for science policy studies and training.

One such research effort is the University of Illinois project on the Social Implications of Science and Technology. It is a computer program for analyzing population problems and alternatives. The system, developed by Paul Handler of the University of Illinois, is usable for instruction in demography as well as for policy analysis and public education in that it enables a person, through a keyboard similar to that of a typewriter, to type out assumptions about demographic variables for a broad range of countries and time periods and then to observe the effects of these assumptions, as portrayed on a display screen through graphs, tables, population growth curves, and age pyramids.

The system can be operated via long distance telephone, which links the keyboard and screen to the computer program at the University of Illinois, and has been demonstrated in Washington, D.C., to various groups.

With assistance from the Agency for International Development, Professor Handler is currently using the system to train groups of population officials from less developed nations concerning the dynamics of population for their respective countries. Each official is thereby enabled to experiment with and to perceive the effects of changing the value of various demographic variables for his own country. Additional variables and information of use to policy-makers are being added to the system, for example, data on the labor force, migration, and a demand for energy based on a per capita consumption schedule.

As the result of the addition of new data, the computer program will become even more useful in that it will enable policy-makers to analyze the effects of alternative rates of population growth for a whole range of problem areas such as the environment and the demand for resources and services.

PUBLIC UNDERSTANDING OF SCIENCE

Science and technology continue to be essential to our standard of living and quality of life but are often viewed by the nonscientist as remote from the general public's comprehension and control. Better public understanding of the potential and limitations of science and technology is particularly critical at present, as decisions on those many issues which are profoundly influenced by science and technology — the environment, energy, population, etc. — must ultimately be made by citizens themselves through the democratic process. The importance of this was stressed by the President in his 1972 Message on Science and Technology when he said: "As our national life is increasingly permeated by science and technology, it is important that public understanding grow apace." The National Science Board, in its annual report to Congress in 1972, also made a major recommendation that the National Science Foundation undertake efforts to enhance public understanding of technology and how it differs from science.

The Public Understanding of Science Program seeks to encourage meaningful communication between scientists and engineers and the public on the role and substance of science and technology. This involves communicating the "facts" of science and an understanding of the relationships of science to the society we live in and the use of science and technology in meeting current and emerging societal problems.

In fiscal year 1972, the Foundation made 20 awards amounting to $794,000 for public understanding of science projects. These included books, films, and seminars on science for nonscientists, support for youth-oriented activities and community and regionally based programs. Productive working relationships were also established during this period with other groups and organizations interested in furthering public understanding of science including private foundations and professional scientific and technical societies.

Specific projects supported included funding of two television films produced by the American Institute of Physics — one film on stellar evolution and the other on the relationships of physics to the biosciences. Both of these films will be shown over the public television stations. Another film project receiving support is the Battelle Memorial Institute's production of a 1-hour program on the "State of Science in the Seventies." This program is scheduled to be shown over television during the 1972-73 season. An award was made to Rockefeller University for the preparation of a book for lay readers on the relationships between basic research and societal needs. Distinguished scientists will write sections of the book dealing with their own areas of expertise.

In addition to support provided individual projects such as books, films, and exhibits, the program also provided support to several multipurpose programs in public understanding of science at national, regional, and community levels. The American Association for the Advancement of Science received support for a number of specific science activities including films and television programs, special publications on scientific and technical topics, seminars for public and civic leaders on scientific issues, and science information services for the media. In what may become a prototype of a new regional-type activity, the School of Journalism at the University of Missouri, Columbia, is conducting a planning study on needs and opportunities in the Midwest for a public understanding of science program. The school will also conduct a series of seminars on science and scientific issues for newspaper editors in the region. In California, Sonoma State College has introduced a pilot program designed to bring to the public in that region a new awareness of the contributions of science to the solution of regional and local environmental problems. "Town Hall" sessions are planned between scientists and civic leaders, and a series of videotapes will be produced and shown by local cable television stations to further illustrate various environmental concerns facing the region.

A mock public hearing on the issue of land development for recreation culminates a 4-day Seminar on Environmental Arts and Sciences held at Aspen, Colo.

Institutional Programs

In fiscal year 1972, the Foundation made the final awards under the former program of University Science Development and continued, on a reduced scale, its program of Institutional Grants for Science. The administration of grants made through these two programs was transferred during the year to the Foundation's Grants and Contracts Office.

UNIVERSITY SCIENCE DEVELOPMENT

The President's Science Advisory Committee in 1960 issued a statement (the Seaborg report) urging Federal action to increase the number of excellent university centers of science. The committee hoped that instead of the "fifteen or twenty [centers of excellence] today, there will be thirty or forty in another fifteen years." Since 1964, the Foundation has sought to help reach that goal. In fiscal year 1972, the final grants were made under the University Science Development (USD) Program. In all, 31 universities have received USD awards, and the progress they have shown gives reason to believe that the hope expressed in the Seaborg report may become actuality.

Of the universities that had earlier obtained USD support for the first stage of their science improvement plans, nine had not had an opportunity to apply for supplemental awards when the program was suspended in fiscal year 1971. In January 1972, however, the Office of Management and Budget released funds specifically for supplemental USD awards to those eligible institutions whose progress under the initial grants merited further assistance.

The following universities received supplemental USD grants for 2 years of further improvement: Carnegie-Mellon, Duke, Florida State, Indiana, Michigan State, New York, Pittsburgh, Purdue, and Vanderbilt. The grants, which totaled $9 million, ranged from $300,000 to $1,600,000. In all instances, the awards were for continuing and consolidating the gains made under the initial grants. The universities themselves have contributed substantially to the improvement programs aided by the Foundation; therefore, the nine supplemental awards were designed to assist the universities to phase into their own budgets the increased costs incurred during the development process.

Through the USD program and the related Departmental Science Development Program, which was also terminated in fiscal year 1971, the Foundation has granted $230 million to 102 universities in achieving higher levels of quality in education and research in 260 departments or areas of science and engineering. The Foundation believes that this investment will not only ensure a strong academic base for the continued advancement of science but will also provide a much wider national distribution of the opportunities and benefits emanating from good universities.

INSTITUTIONAL GRANTS FOR SCIENCE

Institutional Grants for Science provide general support for science annually to about one-fourth of the nation's colleges and universities. Each grant is computed by applying a graduated arithmetical formula to the amount of an institution's Federal research support during the preceding year.

In fiscal year 1972, the Foundation made 628 institutional grants totaling $12 million. Each of the 50 States, the District of Columbia, Puerto Rico, Guam, and the Virgin Islands had one or more institutions receiving grants, all but one of which were under $100,000. The average grant was $19,100—about $3,000 less than in fiscal year 1971, and only a little over half the average of 6 years before. Since the program began in fiscal year 1961, over 1,000 colleges and universities have received institutional grants amounting to $120.4 million.

Three-fourths of the fiscal year 1972 institutional grant funds were awarded to universities granting doctor's degrees, about one-sixth to master's grantors, and about one-tenth to colleges offering only undergraduate programs. The accompanying figure shows, for the entire span of the program from 1961 through 1972, the number of participating institutions in each of these three groups and each group's share of the total amount of institutional grant dollars.

Institutional officials decide how the grant funds are to be spent. The methods of determining priorities with respect to the use of institutional grant funds vary considerably among the participating colleges and universities. There is an increasing tendency, however, to vest control of the funds in special committees whose primary purpose is to set institutional guidelines and criteria for allocating the funds.

Table 11 shows how the recipients of institutional grants have used the funds since the beginning of the program through fiscal year 1971.

Equipment and supplies (including scientific books and periodicals) account for half the expenditures — considerably more than half for institutions offering only undergraduate programs. Salaries and stipends represent nearly 30 percent of the expenditures; doctoral-level institutions, many of which have especially used the grants to encourage their younger faculty members to initiate research projects, spend a larger proportion of their funds for faculty salaries than do undergraduate colleges. Most of the facilities expenditures are for renovation of science laboratories or

INSTITUTIONAL GRANT AWARDS FOR FISCAL YEARS 1961-1972

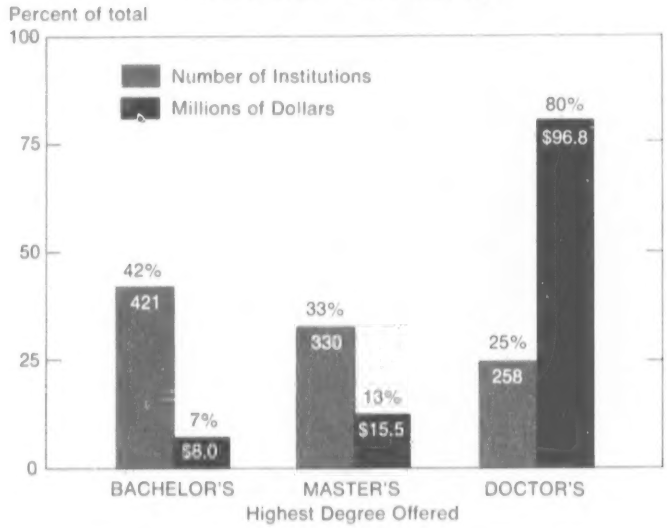


Table 11
Uses of Institutional Grant Funds
Fiscal Years 1962-71
(Millions of Dollars)

A. Type of use:	Amount spent [1]	Percent of total expenditures
Equipment and supplies	$47.2	50.8
General	43.4	46.2
Libraries	3.8	4.0
Facilities	15.2	16.2
General	10.4	11.1
Computers	4.8	5.1
Personnel	27.0	28.8
Faculty salaries	12.7	13.5
Graduate assistants	5.4	5.7
Other student stipends	2.6	2.8
Visiting lecturers	1.4	1.5
Technicians' salaries	2.5	2.7
Other	2.4	2.6
Travel	2.3	2.4
All other	2.3	2.4
Total	$94.0	100.0

B. Field of science:	Amount spent [1]	Percent of total expenditures
Physical sciences	$32.1	34.1
Astronomy	1.3	1.4
Chemistry	16.5	17.5
Physics	13.0	13.8
Other	1.3	1.4
Mathematical sciences	4.8	5.1
Environmental sciences	7.8	8.3
Atmospheric science	.9	1.0
Earth sciences	5.4	5.7
Oceanography	1.5	1.6
Engineering	11.9	12.7
Life sciences	20.1	21.3
Psychology	4.0	4.3
Social sciences	6.2	6.6
All other (inter- and multidisciplinary)	7.1	7.6
Total	$94.0	100.0

[1] From awards made fiscal years 1961-69. Total amount of awards, $93.9 million; total expenditures fiscal years 1962-70, $82.0 million.

for relatively inexpensive new construction. The physical sciences have received about one-third of the funds, and the life sciences about one-fifth. Percentage allocations to social sciences and psychology tend to be higher in universities than in colleges where instructional equipment for natural science laboratories had the highest priority.

Institutional administrators value the grants highly because the funds are discretionary, flexible, and immediately available. By shifting decision-making to the campus, the grants provide a means of building up or restoring institutional loyalty among faculty members. They also enable institutions to fill gaps and respond to opportunities, which may not require large amounts of money but for which only the institutional grant may be at hand. During a time of shrinking revenues for colleges and universities, institutional grants have furnished a small but important resource for sustaining academic science.

Appendix A

National Science Board, NSF Staff, Advisory Committees and Panels

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Terms Expire May 10, 1976

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Hubert Heffner, Chairman, Department of Applied Physics, Stanford University, Stanford, Calif.

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Joseph M. Reynolds, Boyd Professor of Physics and Vice President for Instruction and Research, Louisiana State University, Baton Rouge, La.

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*H. Guyford Stever, Director, National Science Foundation, Washington, D.C. (Chairman, Executive Committee)

* * *

Vernice Anderson, Executive Secretary, National Science Board, National Science Foundation, Washington, D.C.

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Hamden, Conn.

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Department of Biochemistry and Biophysics
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President (Retired), Submarex

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Woods Hole Oceanographic Institution

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Ocean Systems, Inc.

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Nicholas Fofonoff
Woods Hole Oceanographic Institution

Heinz G. Fortak
Institut fur Theoretische Meteorologie
der Ferien
Universitate Berlin (Germany)

Walter Munk
Department of Geophysics
University of California, San Diego

Gerhard Neumann
Department of Meteorology and Oceanography
New York University

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Department of Oceanography
Texas A&M University

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Woods Hole Oceanographic Institution

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Ted Chwirut
Chief, Division of Small Ships
Office of Ship Construction
Maritime Administration

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National Ocean Survey
National Oceanic and Atmospheric
Administration
U.S. Department of Commerce

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Special Assistant for Environmental Quality
Office of the Oceanographer of the Navy

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University of California, San Diego

James Gibbons
School of Marine and Atmospheric Sciences
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Marine Superintendent
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Marine Geology
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Scripps Institution of Oceanography
University of California, San Diego

William M. Sackett
Department of Oceanography
Texas A&M University

Proposal Review Panel for the International Decade of Ocean Exploration

John I. Ewing
Lamont-Doherty Geological Observatory
Columbia University

Donald V. Hansen
Atlantic Oceanographic Laboratories
National Oceanic and Atmospheric
Administration
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George Keller
Atlantic Oceanographic Laboratories
National Oceanic and Atmospheric
Administration
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Naval Research Laboratory

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Skidaway Institute of Oceanography

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Scripps Institution of Oceanography
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Appendix B

Organization Changes and Appointments

OFFICE OF THE DIRECTOR

Dr. H. Guyford Stever was appointed by the President as Director of the National Science Foundation. Dr. Stever, formerly the President of Carnegie-Mellon University, took the oath of office as Director on February 1, 1972.

Dr. William D. McElroy, who had been the Director of the Foundation since July 14, 1969, resigned to become Chancellor of the University of California, San Diego.

Several changes occurred affecting the Director's Staff Assistants. Dr. J. Merton England, who had been serving as Executive Assistant to the Assistant Director for Institutional Programs, was appointed Special Assistant, and Mr. Charles Maechling, Jr., formerly the Deputy General Counsel, was also assigned to the Director's Office as Special Assistant.

RESEARCH AND DEVELOPMENT STUDIES GROUP

The Director established a Research and Development Studies Group on May 5, 1972, which is responsible for organization and planning efforts leading to the implementation of two new fiscal year 1973 programs—the R&D Assessment Program and the Experimental R&D Incentives Program.

ASSISTANT DIRECTOR FOR RESEARCH

A new Division of Materials Research was established in the directorate in July 1971.

ASSISTANT DIRECTOR FOR RESEARCH APPLICATIONS

A new Office of Systems Integration and Analysis was established in the directorate in December 1971.

ASSISTANT DIRECTOR FOR ADMINISTRATION

A new Management Information Office was established in May 1972. This office combines the functions of the Management Information Systems Project and the Data Management Systems Office.

ASSISTANT DIRECTOR FOR INSTITUTIONAL PROGRAMS

The Directorate for Institutional Programs was disestablished in January 1972. The residual activities of the directorate were transferred to the Grants and Contracts Office (Administration Directorate).

STAFF CHANGES

In addition to the appointments mentioned above, the following key staff appointments were announced during the year.

Keith R. Kelson, Acting Assistant Director for Education.

Thomas E. Jenkins, Acting Assistant Director for Administration.

Bodo Bartocha, Head, Office of International Programs.

Harold W. Paxton, Director, Division of Materials Research.

Frederick H. Abernathy, Director, Division of Engineering.

Philip L. Johnson, Director, Division of Environmental Systems and Resources.

Sidney Sternberg, Deputy Assistant Director for Research Applications.

George Pilarinos, Head, Management Information Office.

Fred K. Murakami, Head, Management Analysis Office.

RESIGNATIONS

Leon Schwartz, Deputy Assistant Director for Program Management, Research Applications Directorate, left the Foundation to accept the position of Assistant Director for Administration, National Institutes of Health.

Lloyd G. Humphreys, Assistant Director for Education, left the Foundation to accept a position as Professor of Psychology at the University of Illinois.

Franklin C. Sheppard, Acting Deputy Assistant Director for Administration, retired from Federal service after more than 20 years with the Foundation.

Louis Levin, Special Assistant to the Director, left the Foundation to accept the position of Special Consultant to the President of Texas Tech University.

David E. Ryer, Special Assistant to the Director, left the Foundation to accept the position of Assistant Chancellor at the University of California, San Diego.

Douglas L. Brooks, Special Assistant to the Director, left the Foundation to accept the position of Executive Director of the National Advisory Committee on Oceans and Atmosphere, Department of Commerce.

Bernard Sisco, Special Assistant to the Director, left the Foundation to accept the position of Vice Chancellor for Administration at the University of California, San Diego.

CHANGES IN THE NATIONAL SCIENCE BOARD

The terms of the following seven members of the National Science Board expired on May 10, 1972: Dr. Charles F. Jones (Vice Chairman of the Board, Humble Oil & Refining Co., Houston, Tex.); Dr. Thomas F. Jones, Jr. (President, University of South Carolina); Dr. Robert S. Morison (Professor of Science and Society, Program on Science, Technology, and Society, Cornell University); Dr. E. R. Piore (Member, Board of Directors, International Business Machines Corp., Armonk, N.Y.); Dr. Joseph M. Reynolds (Boyd Professor of Physics and Vice President for Instruction and Research, Louisiana State University); Dr. Athelstan F. Spilhaus (Fellow, Woodrow Wilson International Center for Scholars, Smithsonian Institution, Washington, D.C.); and Mr. Richard H. Sullivan (Assistant to the President, Carnegie Corp. of New York).

The following changes occurred in the institutional affiliations and academic positions of certain members: Dr. H. Guyford Stever, from President, Carnegie-Mellon University, to Director, National Science Foundation (Dr. Stever's term on the Board was to expire on May 10, but he resigned to become Director); Dr. William D. McElroy resigned as Director, National Science Foundation; Dr. R. H. Bing spent the academic year as Visiting Professor of Mathematics, University of Texas at Austin; Dr. H. E. Carter, from Vice Chancellor of Academic Affairs, University of Illinois, to Coordinator of Interdisciplinary Programs, University of Arizona; and Dr. Roger W. Heyns, from Professor of Psychology and Education, Department of Psychology, University of Michigan, to President, American Council on Education, Washington, D.C.

Financial Report for Fiscal Year 1972

Appendix C

Salaries and Expenses Appropriation

Fund Availability

Fiscal year 1972 appropriation	$619,000,000	
Unobligated balance carried forward from fiscal year 1971	10,355,742	
Transfer to GSA for rent	88,345	
Fiscal year 1972 availability		$629,267,397

Net Obligations

Scientific research project support:		
Atmospheric sciences	$11,705,659	
Earth sciences	9,482,832	
Oceanography	12,550,143	
Biological sciences	54,001,038	
Physics	33,276,917	
Chemistry	24,521,802	
Astronomy	8,008,244	
Mathematical sciences	13,746,300	
Social sciences	22,454,380	
Engineering	25,432,529	
Materials research	33,394,568	
Subtotal, scientific research project support		$248,574,412
National and special research programs:		
International biological program	$ 9,443,625	
Global atmospheric research program	2,391,013	
International decade of ocean exploration	19,671,443	
Ocean sediment coring program	9,257,608	
Arctic research program	3,544,029	
U.S. Antarctic research program	27,000,239	
Oceanographic facilities and support	14,522,578	
1973 Solar eclipse (Logistic support)	55,166	
Subtotal, national and special research programs		$ 85,885,701
National research centers:		
National Astronomy and Ionosphere Center at Arecibo	$ 4,687,500	
Kitt Peak National Observatory	7,699,881	
Cerro-Tololo Inter-American Observatory	2,500,000	
National Radio Astronomy Observatory	6,669,900	
National Center for Atmospheric Research	18,177,416	
Subtotal, national research centers		$ 39,734,697
Computing activities	$20,915,968	
Science information activities	9,710,922	
International cooperative scientific activities	4,244,813	
Research applied to national needs:		
Advanced technology applications	18,913,508	
Environmental systems and resources	19,448,881	
Social systems and human resources	10,719,202	
Exploratory research and problem assessment	4,685,298	
Subtotal, research applied to national needs		$ 53,766,889
Intergovernmental science program	$ 1,078,003	
Institutional improvement for science	20,961,406	
Graduate student support	20,339,901	
Science education improvement	65,016,034	
Planning and policy studies	2,929,466	
Program development and management	24,562,052	
Subtotal		$597,720,263
Unobligated balance carried forward to fiscal year 1973		31,547,134
Total		$629,267,397

Scientific Activities (Special Foreign Currency) Appropriation

Receipts

Fiscal year 1972 appropriation	$ 3,000,000

Obligations

Total obligations for fiscal year 1972	$ 2,999,598
Balance lapsing	402
Total	$ 3,000,000

Trust Fund

Receipts

Unobligated balance brought forward from fiscal year 1971	$ 4,802
Donations from private sources	1,646
Total availability	$ 6,448

Obligations

Total availability	$ 6,448
Less unobligated balance carried forward to fiscal year 1973	5,159
Total obligations	$ 1,289

Appendix D

Patents Resulting from Activities Supported by the National Science Foundation

The Foundation, since its last annual report, has received notification of the issuance of the following seven patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities on each of which the U.S. Government has received a nonexclusive, irrevocable, nontransferable, paid-up, worldwide license:

Patent No. 3,569,734 entitled "Pulse and Frequency Counter" was issued on March 9, 1971, on an invention made by Gary L. Samuelson and David C. Ailion in the course of research supported by a grant to the University of Utah. The invention is a compact, multipurpose counter constructed by interconnecting two solid state decimal counters with a solid state switching circuit constructed by inverting NOR gates.

Patent No. 3,601,607 entitled "Step-Scanning System for Mass Spectrometer" was issued on August 24, 1971, on an invention made by Jerald Wasserburg, Curtis A. Bauman, Emil V. Neno, and Dimitri A. Papanastassiou in the course of research supported by a grant to the California Institute of Technology. The invention is a single focusing 60° sector magnet mass spectrometer.

Patent No. 3,607,700 entitled "Electrode for Measuring Potassium and Other Specific Ion Contents" was issued on September 21, 1971, and Patent No. 3,616,409 entitled "Electrode System for Measuring Ion Activities in Stream or Sample" was issued on October 26, 1971, on inventions made by Daniel C. Tosteson in the course of research supported by a grant to Duke University. The inventions relate to the measuring of the activity of a particular chemical species of ion in an aqueous solution.

Patent No. 3,627,404 entitled "Electrical Focusing Device" was issued on December 14, 1971, on an invention made by Wen-Chung Wang in the course of research supported by a grant to the Polytechnic Institute of Brooklyn. The invention relates to the focusing of light by electrical means.

Patent No. 3,643,184 entitled "Multi-port Feedback and Pole-Zero Control" was issued on February 15, 1972, on an invention made by John R. D'Alessandro in the course of research supported by a grant to Columbia University. The apparatus and methods disclosed under the patent allow the critical frequencies (poles and zeros) to be independently controlled by applying state-variable feedback techniques to both the external and internal ports of an arbitrary linear, passive and time-invariant network (system).

Patent No. 3,657,083 entitled "Disc Jet Electropolishing Method and Apparatus" was issued on April 18, 1972, on an invention made by John M. Larson, Douglas Hugh Polonis, and Raymond Taggart in the course of research sponsored by a grant to the University of Washington. The invention is a jet electropolishing apparatus and method for preparation of thin foil specimen discs for transmission electron microscopy.

The Foundation, since its last annual report, has also received notification of the issuance of the following two patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities which the inventors have assigned to the U.S. Government as represented by the National Science Foundation:

Patent No. 3,524,609 entitled "Method and Apparatus for Launching Balloons" was issued on August 18, 1971, on an invention made by [illegible]an W. Sparkman and William E. Humphrey in the course of research supported under a contract with the University Corporation for Atmospheric Research at the National Center for Atmospheric Research, Boulder, Colo. The invention relates to an apparatus for launching balloons which may carry scientific instruments and other equipment for meteorological and other atmospheric experiments.

Patent No. 3,613,992 entitled "Weather Modification Method" was issued on October 19, 1971, on an invention made by Robert C. Knollenberg in the course of research supported under a contract with the University Corporation for Atmospheric Research at the National Center for Atmospheric Research, Boulder, Colo. The invention provides a method for producing rain or snow from natural atmospheric clouds using seeding agents characterized by a high solubility in water and a large endothermic heat of solution in water.

Appendix E

Publications of the National Science Foundation Fiscal Year 1972

1 Research Applied to National Needs (RANN), Interim Description and Guidelines for Proposal Preparation (NSF 71-21)
2 National Science Foundation Guide to Programs (NSF 71-22)
3 *Mosaic*, Vol. II, No. 2 (NSF 71-23)
4 Science Resources Studies Highlights: "Federal R&D Funding Shows Upward Trend" (NSF 71-24)
5 An Analysis of Federal R&D Funding by Budget Function, 1960-72 (NSF 71-25)
6 Science Resources Studies Highlights: "Unemployment Rates for Scientists, Spring 1971" (NSF 71-26)
7 Graduate Student Support and Manpower Resources in Graduate Science Education, Fall 1970 (NSF 71-27)
8 Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, Fiscal Year 1970 (NSF 71-28)
9 Engineering Research Initiation Grants (NSF 71-29)
10 Science Resources Studies Highlights: "Enrollments Increase in Science and Mathematics in Public Secondary Schools 1948-49 to 1969-70" (NSF 71-30)
11 *Mosaic*, Vol. II, No. 3 (NSF 71-31)
12 Science Resources Studies Highlights: "Estimated Academic R&D Direct Price Trends 50 Percent Higher Over Decade 1961-71" (NSF 71-32)
13 Science Resources Studies Highlights: "Unemployment Rate for Engineers, June-July 1971" (NSF 71-33)
14 International Decade of Ocean Exploration (NSF 71-34)
15 Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1970, 1971, 1972, Vol. XX (NSF 71-35)
16 Grants for Improving Doctoral Dissertation Research in the Field Sciences (NSF 71-36)
17 Grants for Improving Doctoral Dissertation Research in the Social Sciences (NSF 71-37)
18 Course Content Improvement Program (NSF 71-38)
19 Science Resources Studies Highlights: "Industrial R&D Spending, 1970" (NSF 71-39)
20 *Mosaic*, Vol. II, No. 4 (NSF 71-40)
21 India-United States Exchange of Scientists (NSF 71-41)
22 Science Resources Studies Highlights: "Undergraduate Enrollments in Science and Engineering" (NSF 71-42)
23 Research Applied to National Needs (NSF 71-43)
24 National Science Foundation Special Foreign Currency Program for Research, Science Education and Related Activities (NSF 71-44)
25 American Science Manpower, 1970 (NSF 71-45)
26 Scientists and Engineers in Economic Development Program (NSF 71-46)
27 Science Resources Studies Highlights: "Federal Scientific, Technical, and Health Personnel in 1970" (NSF 71-47)
28 The Role of Engineers and Scientists in a National Policy for Technology (NSB 72-1)
29 Twenty-First Annual Report, 1971, National Science Foundation (NSF 72-1)
30 Grants and Awards, 1971, National Science Foundation (NSF 72-2)
31 National Science Foundation Databook (NSF 72-3)
32 Intergovernmental Science Program (NSF 72-4)
33 Administrative Guide for the 1972 National Science Foundation Graduate Traineeship Program (NSF 72-5)
34 Publications of the National Science Foundation (NSF 72-6)
35 Grants for Education in Science (NSF 72-7)
36 1972-73 Directory, In-Service Institutes for Secondary School Teachers and Supervisors of Science, Mathematics, and Social Sciences (NSF 72-8)
37 Inventory of Computers in U.S. Higher Education 1969-70, Utilization and Related Degree Programs (NSF 72-9)
38 *Mosaic*, Vol. III, No. 1 (NSF 72-10)
39 Supplementary Information for the Support of Research Workshops and Symposia (NSF 72-11)
40 Institutional Grants for Science (NSF 72-12)
41 National Science Foundation Special Foreign Currency Program for Research, Science Education and Related Activities (NSF 72-13)
42 Cooperative Science Programs: Romania, Hungary, Czechoslovakia, Bulgaria (NSF 72-14)
43 *Mosaic*, Vol. III, No. 2 (NSF 72-15)
44 National Science Computer Network (NSF 72-16)
45 National Patterns of R&D Resources, Funds and Manpower in the United States, 1953-72 (NSF 72-300)
46 Federal Funds for Academic Science, Fiscal Year 1970 (NSF 72-301)
47 Science Resources Studies Highlights: "Manpower and Financial Resources Allocated to Academic Science and Engineering Activities, 1965-71" (NSF 72-302)
48 Papers and Proceedings of a Colloquium on R&D and Economic Growth/Productivity (NSF 72-303)

49 SCIENTIFIC HUMAN RESOURCES: PROFILES AND ISSUES (NSF 72-304)

50 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Functions Other than Defense and Space Show Rising Share in Federal R&D Expenditures" (NSF 72-305)

51 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Total Scientific and Technical Personnel in Industry Remains Level, R&D Personnel Lower in 1970" (NSF 72-306)

52 UNEMPLOYMENT RATES AND EMPLOYMENT CHARACTERISTICS FOR SCIENTISTS AND ENGINEERS, 1971 (NSF 72-307)

53 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "First-Year, Full-Time Graduate Science Enrollment Continues to Decline" (NSF 72-308)

54 RESEARCH AND DEVELOPMENT IN INDUSTRY, 1970. FUNDS, 1970; SCIENTISTS AND ENGINEERS, JANUARY, 1971 (NSF 72-309)

55 A PRICE INDEX FOR DEFLATION OF ACADEMIC R&D EXPENDITURES (NSF 72-310)

56 SCIENCE RESOURCES STUDIES HIGHLIGHTS: "Changes in Graduate Programs in Science and Engineering, 1970-72 and 1972-74" (NSF 72-311)

57 INITIAL REPORTS OF THE DEEP SEA DRILLING PROJECT, Vol. VII (NSFSP-7)

58 INITIAL REPORTS OF THE DEEP SEA DRILLING PROJECT, Vol. VIII (NSFSP-8)

59 INITIAL REPORTS OF THE DEEP SEA DRILLING PROJECT, Vol. IX (NSFSP-9)

60 INITIAL REPORTS OF THE DEEP SEA DRILLING PROJECT, Vol. X (NSFSP-10)

61 INITIAL REPORTS OF THE DEEP SEA DRILLING PROJECT, Vol. XI (NSFSP-11)

Appendix F

National Research Centers Contractors

Associated Universities, Inc. (AUI)

Gerald F. Tape, President

National Radio Astronomy Observatory
David S. Heeschen, Director

AUI Member Universities:
Columbia University
Cornell University
Harvard University
The Johns Hopkins University
Massachusetts Institute of Technology
University of Pennsylvania
Princeton University
University of Rochester
Yale University

Association of Universities for Research in Astronomy, Inc. (AURA)

Gilbert Lee, President

Cerro Tololo Inter-American Observatory
Victor M. Blanco, Director
Kitt Peak National Observatory
Leo Goldberg, Director

AURA Member Universities:
University of Arizona
California Institute of Technology
University of California
University of Chicago
Harvard University
Indiana University
University of Michigan
Ohio State University
Princeton University
University of Texas at Austin
University of Wisconsin
Yale University

Cornell University

W. Donald Cooke, Vice President for Research

National Astronomy and Ionosphere Center
Frank D. Drake, Director, Ithaca, N.Y.
Tor Hagfors, Director, Observatory Operations, Arecibo, Puerto Rico

University Corporation for Atmospheric Research (UCAR)

Walter Orr Roberts, President

National Center for Atmospheric Research
John W. Firor, Director

UCAR Member Universities:
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University of Arizona
California Institute of Technology
University of California
The Catholic University of America
University of Chicago
Colorado State University
University of Colorado
Cornell University
University of Denver
Florida State University
Harvard University
University of Hawaii
The Johns Hopkins University
University of Illinois at Urbana-Champaign
University of Maryland
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McGill University
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